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ABSTRACT

This book describes transdisciplinary management of multiply disabled children with vision problems and presents four theoretical models of visual assessment and three illustrative case studies in a sequence appropriate to the learning process. The first three models are intended to lead to assessment and management of the child and the last to assessment and management of the child's environment. The models are: (1) medical (anatomy, physiology, pathology of the optical and neural visual system); (2) educational (visual perception and learning); (3) developmental (reflexive and voluntary eye movements, relationship between visual and motor processes); and (4) functional (visual components of daily living, assessment of the environment). After an introductory section, Part One presents the theoretical rationale in a discussion of each of the four models as applied to the cases. Part Two describes developmental vision assessment including evolution of the Erhardt Developmental Vision Assessment instrument and models for assessment. Part Three first offers a model for management of visual-motor dysfunction and then applies the principles of assessment to management of each of the three cases. The final chapter offers a summary including a synthesis of models for visual-motor assessment and management. A glossary defines technical terms. References are included with each chapter. (DB)

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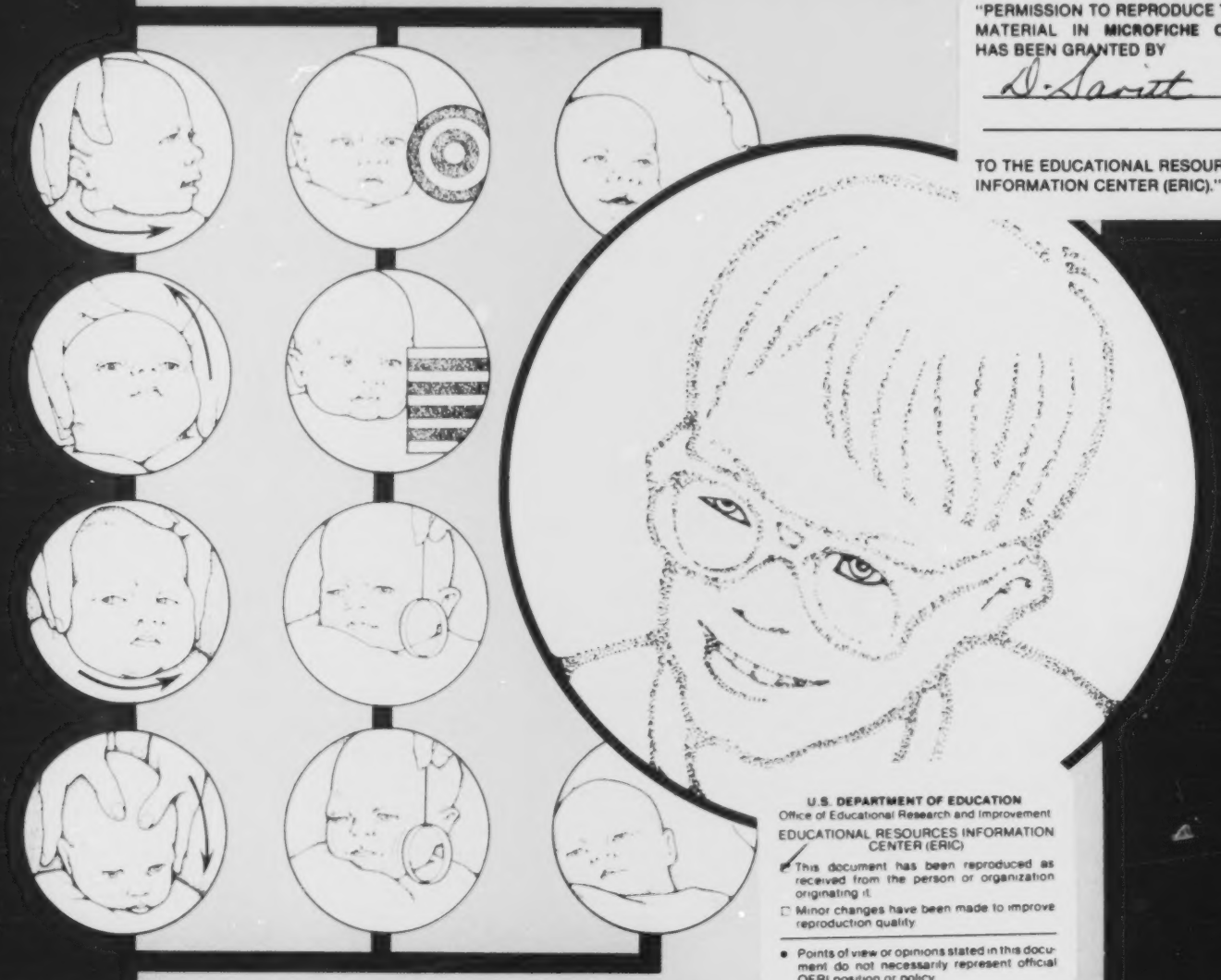
DEVELOPMENTAL VISUAL DYSFUNCTION

Models for Assessment and Management



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DEVELOPMENTAL VISUAL DYSFUNCTION

Models for Assessment and Management

Rhoda Priest Erhardt, M.S., OTR, FAOTA
Illustrations drawn under contract by Gary Baune

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This book is dedicated to

My father, who, by his example, instilled in me an appreciation of the value of hard work, self-discipline, and an enduring thirst for knowledge,

and

My mother, who, by expressing her artistic talents throughout her personal and professional life, served as a model for my own creative process.

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Photographs by Shari and David Yardley: Melinda (p. xiii), figures 2-2 through 2-9

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About the Author

Rhoda Priest Erhardt, M.S., OTR, FAOTA, received her bachelor of science degree in occupational therapy from the University of Illinois and her masters degree in child development and family relations from North Dakota State University. She was certified in pediatric neurodevelopmental treatment (NDT) in London, England.

Mrs. Erhardt is currently in private practice, providing evaluation and consultation services to a variety of health agencies and educational systems in the Midwest, as well as presenting workshops throughout the world. She was formerly the director of the Easter Seal Mobile Therapy Unit in Fargo, North Dakota. She has served on the editorial board of the *American Journal of Occupational Therapy* and the Board of Occupational Therapy Practice of the state of North Dakota, and was enrolled in the American Occupational Therapy Association Roster of Fellows in 1983.

Mrs. Erhardt is the author of *Developmental Hand Dysfunction* and the creator of a developmental prehension assessment for neurologically impaired children. Her videotape on normal hand development received an award from the American Academy for Cerebral Palsy and Developmental Medicine. She has also created a developmental visual assessment and a videotape on normal visual development. The assessment is included in this volume as well as being available separately.

Preface and Acknowledgments

As an occupational therapist specializing in pediatrics, cerebral palsy, and hand function, I have always been intrigued and puzzled by the unique visual problems of children with developmental disabilities. One of my first challenges, in the early 1970s, was to provide effective assessment and treatment for children with visual-perception or perceptual-motor problems. I reported on some of this work in *The American Journal of Occupational Therapy* in 1971.

As my caseload gradually changed to include individuals with cerebral palsy as well as those with learning disabilities, I became increasingly aware that fine-motor function could not be fully understood without consideration of eye-hand coordination. The intensive literature search that resulted in compilation of the Erhardt Developmental Prehension Assessment (EDPA) produced tantalizing bits and pieces of information about vision in conjunction with prehension development, but not in a formal developmental structure.

My own continuing education goals began to focus on presentations given by multidisciplinary teams of educators, optometrists, and occupational therapists. I learned that vision development does proceed in an orderly sequence similar to that of prehension development. A short developmental vision assessment compiled from this new information helped me define treatment objectives and activities, and I began to document significant results in some of my patients. A case report was presented at the American Occupational Therapy Association's national conference in 1986 and also published in 1987 in the Association's journal.

This impetus to improve and expand my developmental vision assessment led to an interesting discovery. The literature was filled with information about visual acuity and pathology (the medical model) and visual perception related to cognitive processing (the educational model). Relatively little could be found, however, concerning the motor components of vision, particularly the developing of eye-hand linkage. Vision has been described as a process, a manifestation of an integrated, growing action system.

Extrapolation of developmental sequences eventually was accomplished through a review of the literature in child development, developmental psychology, and anthropology, as well as medicine (optometry and ophthalmology) and education (early childhood and special education for the visually impaired).

The process of creating the Erhardt Developmental Vision Assessment (EDVA), as well as this book, followed the same sequence as that for the EDPA and *Developmental Hand Dysfunction* (1982, 1989. Tucson, AZ: Therapy Skill Builders). A videotaped study, *Normal Visual Development: Birth to Six Months* (1986. Fargo, ND: Erhardt Developmental Products), was completed in 1986 with the able assistance of Tom Tollefson of Snyder Film and Video and the gracious cooperation of the parents of the following infants:

Stephanie, daughter of Sandy and Jim Glass
Joshua, son of Lynn and Bob Johnk
Carrie, daughter of Janet and Rick Olson
Hayley, daughter of Deb and Dan Pullen
Nicole, daughter of Donna and
Cliff Rodenburg

An interrater reliability study was completed in 1986 with the assistance of Keith Gustafson, director of the Infant/Toddler Program, Minot State University; Dr. Patricia Beatty, Department of Psychology, North Dakota State University; and Dr. Doris Herstgaard, president of Statistical Associates, Inc.

The following therapists and educators participated as trained raters:

Lyle E. Berg
Pam Galloway
Dianne L. Giessinger
Keith H. Gustafson
Melissa Hamerlik
Mary Klein
Mary Jo Krahn
Mary Jo Larsen
Phyllis LeDosquet
Kathy Lee
Lucille Loftesness
Diane Berg McCormack
Robert L. Morgan
Patricia M. Offerdahl
Carol Olimb
Betty A. Omvig
Wendy Otto
Alan Schulte
Mary Ann Steele
Teresa Ann Zeltinger

Feedback from participants in the many workshops held all over the country was also invaluable in revising the EDVA after the interrater reliability study. Gary Baune, the talented artist who produced all illustrations for the EDPA and the book *Developmental Hand Dysfunction* in 1982, created exciting, accurate, and charming new drawings for the 1989 revision of the EDVA that appears in this book.

This manuscript is designed to follow the same basic format as *Developmental Hand Dysfunction* (theoretical rationale: review of literature and case studies; assessment: evolution and models; management: models and case studies). However, important differences between the subject matter of prehension and vision required some changes in order and method of presentation.

The case studies in *Developmental Hand Dysfunction* illustrated various theoretical approaches and were introduced in the chronological order of my own professional learning process. The scope of vision and its impact on all areas of function, however, is much more complex and required a slightly different approach.

My own clinical experience initially was with the visual perception deficits of children with learning disabilities and later, as my caseload changed, was with the visual-motor problems of those with cerebral palsy, including some with cortical vision impairments. I lacked experience with children whose blindness or low vision was due to optical rather than neural pathology. Although occupational therapists such as myself are exposed to the workings of the visual system during undergraduate education as part of general anatomy and physiology courses, only those choosing to specialize in the field of the visually impaired have the opportunity to use that information and thus retain it. More often, pediatric therapists find themselves challenged by a sizable population of children with either visual perception problems or cerebral palsy and whose visual skills have been variously described as inconsistent, puzzling, questionable, and/or unique.

Like many of these therapists, I also was trying to assess visual function with an inadequate base of physiological knowledge and even more importantly, without the ability to link that knowledge to the specific visual problems of children with perceptual and physical handicaps. Although the programs I had designed to improve visual perception were generally effective and seemed to contribute to better neurological organization in the mildly impaired population, the moderately and severely impaired children displayed eye movement patterns strikingly similar to delayed and abnormal motor patterns throughout their entire bodies.

Neurodevelopmental treatment was my therapy of choice, and as I learned more about visual development, I realized the value of including that information in assessment and treatment. However, the visual problems of many of these children were related to additional pathology of the eye, the optic tracts, or the visual cortex, which had usually occurred in the perinatal or postnatal period.

I realized that a review of the normal structure and function of the eye is essential for understanding visual pathology (the medical model) and its implications for learning, particularly in the school environment (the educational model). The role of vision in areas of growth such as motor also needs to be investigated (the developmental model) to facilitate the best possible quality of life for each individual as an active, competent participant in the home, school, and community (the functional model).

This book presents four theoretical models and three illustrative case studies in an appropriate sequence for the learning process. The first three models lead to assessment and management of the child and the

last to assessment and management of the child's environment.

1. ***medical model:*** anatomy, physiology, and pathology of the optical and neural visual system
2. ***educational model:*** visual perception and learning
3. ***developmental model:*** reflexive and voluntary eye movements, relationship between visual and motor processes
4. ***functional model:*** visual components of daily living, assessment of the environment

As my writing progressed, I also became aware of some major differences in the way intervention activities for prehension and vision needed to be integrated into the children's school and home programs. Prehension goals and objectives had been incorporated into the fine-motor domains of the Individualized Educational Plans, and treatment was usually implemented by occupational therapists and the families. Visual goals and objectives, however, applied to all domains, the traditional (cognitive, communicative, gross motor, self-help, etc.) as well as the newer functional ones (vocational, domestic, leisure, and community). Moreover, the responsibility for implementation needed to be assumed by *every* team member.

Therefore, this book attempts to give concrete examples of transdisciplinary *management*, rather than *treatment*, by a variety of professionals, paraprofessionals, and family members. The list of professionals may include therapists (occupational, physical, speech, music, recreational), teachers (special education, preschool handicapped, infant and toddler stimulation, visually impaired), psychologists (developmental, behavioral, school), eye-care specialists (ophthalmologists, optometrists, orthoptists), and other physicians (pediatricians, neurologists). The transdisciplinary team, which aims for a unified, holistic view of each child, allows for an eclectic approach to vision problems pervading all aspects of life function.

A glossary of terms and definitions is included to facilitate communication among professionals from different disciplines who use different language or have different meanings for similar words.

Three case studies are presented to illustrate theoretical approaches, assessment procedures, and management programs. Appreciation for their cooperative assistance, creative input, and unending patience is extended to:

Joseph Nilles, his mother Carol, father Jerome, sister Laura, brother David, grandfather Herbert, teacher Sherry Johnson, classroom aide Maria Sandry. vision consultant Julie Anderson, occupational therapist Vicki Busker Bedford, physical therapist Maureen Tomaszewski, neuropsychologist Larry Fisher, pediatrician George Johnson, neurologist Generoso Gascon, ophthalmologists I. David Sorgen and Ann Barker Griffith, and optometrist James McLaurin.

Melinda Yardley, her mother Shari, father David, brother Ryan, grandparents Robert and Alline Wright, teachers Melvin Olson and Bev Brakke, management aide Carol Larson, counselor/social worker Paul Neuman, occupational therapist Jan Nelson, physical therapist Pat DuBord, pediatrician Robert Montgomery, ophthalmologist Patrick Colliton, and optometrist Stan Andrist.

Nathan Johnson, his mother Colleen, father Butch, brother Matthew, grandparents Vernon and Betty Becker, teachers Sandra Hendrickson (regular classroom), Terry Olson (adaptive physical education), Renee Pearson (special education), and Paul Weinzierl (learning disability resource), classroom aides Ellen Wallgren and Mary Benham, speech clinician Jeanne Johnson Olson, physical therapists Patricia Kraemer and Theresa Hawkins (aquatic therapy), family physician Tim Schmitt, ophthalmologist G.L. Ness, optometrists Robert Duckman and Joseph Miller, and friends Daniel and Kyle Benham, Angela Peters, and Ned Sundby.

Special thanks is extended to Sally Erhardt for serving as a model of normal adult visual-motor function.

Professional support has been received from Dr. Robert Duckman, College of Optometry, State University of New York, and Dr. I. David Sorgen, Department of Ophthalmology, Fargo Clinic, Merit Care, who both offered valuable additions and revisions to this manuscript. Gratitude is also extended to Marsha Dunn Klein and Irene Topor, who provided constructive critical reviews in the final stages.

Foreword I

The visual assessment of the multiply handicapped child has received much attention over recent decades. It has been very well documented that there is a significantly higher prevalence of all visual anomalies in the multiply handicapped population as compared with normals. And this is where most investigators stop. There is a dearth of material on remediation of these visual anomalies and their effect on the functional capabilities of the child. Yet it is very reasonable to expect that visual anomalies can and do effect function, academic performance, and even social interaction among others. Teachers of the handicapped; occupational, physical, and speech therapists; special educators; and psychologists all would like to know what can be expected of a particular child on the basis of his or her unique visual status, and what if anything can be done to improve or maximize the child's ability to function in the presence of these anomalies.

The little that has been published about function and remediation of the multiply handicapped child who has a visual dysfunction has been written within an isolated discipline. As we all know, however, it is important to employ a transdisciplinary approach when treating a multiply handicapped child. Good communication among involved team members evaluating the "whole" child is essential for the best possible outcome.

In her book, Rhoda Erhardt presents four basic models: medical, educational, developmental, and functional. She then turns her attention to the *children*, Joseph, Melinda, and Nathan. Each child is comprehensively evaluated and analyzed in a transdisciplinary fashion. But Mrs. Erhardt does not stop there. In a logical progression, she sets up *realistic* goals and follows with treatment programs to meet these goals. And the goals are not erudite and abstruse—they are real and necessary, life-work skills that, when met, will help the children function better in the real world. Mrs. Erhardt has impressively accomplished in this book what many have been unable to accomplish in a whole series of books.

In this book, Mrs. Erhardt anticipates and answers the questions of therapists and team members about each child's visual deficits. The book is easy to follow and comprehensive in scope. While it is targeted toward the professional, the book can be used productively by concerned and interested parents.

Robert H. Duckman, O.D., M.A., F.A.A.O.
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Foreword II

The brain fiercely desires to perceive a three-dimensional world. To this end, it will turn, lift, lower, or tilt the head in order to avoid diplopia or dampen nystagmus. It will also suppress a poorly seeing eye to avoid confusing the image from the clearer seeing one. And if a child's visual system is dysfunctional, the additional burden of other developmental anomalies creates problems of immense complexity.

Multiple professions must be involved in working with such a child as well as his or her parents and other caregivers in order to attain ongoing performance goals compatible with each child's abilities. So when dealing with a multiply handicapped child, one asks, "What are the answers?" or even, "What are the questions?" Rhoda Erhardt, in asking the inconceivable, has been able to structure and categorize the unclassifiable. Innovation is a talent that the reader comes to expect from her in progressing through this remarkable book. Witness the posture improvement in Joseph when she "merely" alters the seating mode.

The portrayal of the visual-motor skills of a normal adolescent serves as a graphic counterpoint to the skills of the multiply handicapped. This provides a useful framework for real-life goals thoughtfully established by the author. The lifestyle domains of domestic, leisure, vocation, and community are emphasized. The specifics range from whether the child can detect motion or identify features, to telling time, making change, fixing a snack, or accessing a computer. The system of data collection and the assessment theory are logically presented, fused, and focused on synthesizing a practical and realistic plan for management.

The transdisciplinary approach to the maximal achievement of individual goals for the visually and functionally handicapped child is not only essential—it is common sense. Mrs. Erhardt has illuminated this approach with her research, insight, and enthusiasm. These factors, along with her experience, form a structure and cohesive discipline geared toward the optimal management of the child's achievement goals.

This book is not only highly readable, with excellent illustrations and photographs, but it also presents the material with empathy and sensitivity. I am certain it will not merely adorn a bookshelf. It will be useful to—and used by—the professionals involved with evaluation, therapy, and teaching as well as those who love and care for these children.

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The Children

JOEY

Melinda

Nathan

Introduction: From Infancy to Adulthood—The Children

Among all living creatures, man is the most eye-minded.
Nothing does he treasure more than the apple of his eye.
Myth, language, folklore, proverbs, art, and poetry abound in allusions to the magic, the mystery, the power, the evil, and the charm of the eye.
(Gesell, Ilg, and Bullis 1949, 3)

Joseph

Because of his unusual eye movements, Joseph was taken to an ophthalmologist when he was 9 months old. His eyes did not move together, his right eye was slightly higher than his left, and he seemed to prefer using his left eye. The doctor found some retinal abnormalities and possible optic nerve damage as well as the muscle imbalance that his parents had noticed.

Joseph had many problems related to his prematurity, low birth weight, and breathing difficulties. A brain hemorrhage had left him with damage to the left side of his brain, seizures, and hydrocephalus, which caused his head to enlarge. When he was 14 months old, because of increasing tightness and spasticity in his right arm and both legs, the staff of a hospital physical medicine department taught his mother range-of-motion exercises. By the age of 2, he could sit supported in a chair, roll over (only to the right), and use his left hand to pick up toys. He could not sit alone, crawl, or walk. He held his right hand in a fist most of the time (fig. i-1). A comprehensive occupational therapy home program was begun.

Fig. i-1

Joseph's cerebral palsy, spastic quadriplegia, was considered moderate, but the variety of his associated defects influenced not only his motor development but also his perceptual, language, and emotional development.

The Relationship of Visual Defects to Central Nervous System Dysfunction

A study at George Peabody College for Teachers, Vanderbilt University, identified types of visual impairments in 74 children with cerebral palsy. About half were diagnosed as spastic, a quarter mixed, and the rest a mixture of athetoid, ataxic, rigid, hypotonic, and unspecified cerebral palsy. The most common category was that of motility defects (33%), followed by nystagmus (15%), refractive errors (11%), optic atrophy (8%), and not testable (2%). In addition, 31% of the children were described as having "questionable" visual problems and attending skills (Harley and Altmeyer 1982).

Many of these visual defects are related to the etiology of the cerebral palsy, which involves damage to one or more portions of the brain. Since the brain controls thought, personality, and motor behavior, lesions in various areas can damage different functions to different degrees. Disabilities associated with neuromotor dysfunction may include sensory (visual, auditory), mental (intellectual, emotional, behavioral), perceptual (visual, auditory, motor, tactile), and neurological (seizure disorders).

Because of the more obvious motor and speech disabilities associated with cerebral palsy, other subtle deficits such as ocular abnormalities can go undetected or may be considered secondary in importance. In addition to motility and refractive errors (myopia, hyperopia, and astigmatism), optic nerve and retinal dysfunction resulting in visual field defects can contribute to visual-perceptual problems requiring special considerations in educational programming (Harley and Altmeyer 1982).

Melinda

When Melinda was 2½ years old, she liked crawling all over the house, pulling herself up to the furniture, and walking around it on tiptoes. Her balance wasn't good enough for her to walk by herself, and when she fell, her arms didn't reach out to protect her head. Her eyes were slightly crossed, and she had trouble using her eyes and hands together, even in her favorite sitting position where she was most steady and comfortable (fig. i-2).

Fig. i-2

Melinda had a mild form of cerebral palsy, which had caused some delays in motor skills and language. After a comprehensive evaluation at a child development center, she began receiving a home program that included occupational therapy, speech therapy, and infant stimulation by a public health nurse and a developmental specialist.

Re-evaluation at age 3½ showed gains in both receptive and expressive language and quantity and quality of motor skills. At that time, Melinda's difficulties in eye-hand coordination and visual perception were identified, and further programming in those areas as well as eye surgery was recommended.

Importance of the Eyes in Perceptual Development

Ray Barsch (1968, 40) described the human organism as "a constant seeker of data . . . designed to thrive on information." The eyes of the newborn receive visual sensations, are alert to certain stimuli, and follow objects dangled before them, but a long time passes until the brain learns how to interpret visual images and understand the messages from the eyes (Nilsson 1966, 1977).

During the first six months of life, particularly the first two, the infant's visual processing is primarily reflexive, immature, global, and disorganized. It gradually becomes integrated with total body movements, which are also becoming more voluntary, controlled, and goal directed. Not until the second half of the first year does visual perception begin to reach the discriminative level needed to act with the cognitive system for functional tasks. It is no coincidence that increased mobility from seven months onward provides the baby with the opportunity to explore space, interpret the three-dimensional domain, and construct a perceptual model (Langley, Nelson, and Padula 1986).

Cognition is defined as the act of perceiving and knowing (Barnhart 1975), while perception is defined as the recognition of sensory information produced by different stimuli in the external environment (de Quiros and Schrager 1978, 1979). Perception is generally considered an acquired skill.

Visual perception is defined as the capacity to interpret sensory input, recognize similarities and differences, and assign meaning to what is seen. Visual discrimination and perceptual constancy are necessary prerequisites to the acquisition of efficient visual perception. Perceptual constancy cannot be achieved unless the environment is stimulating and variable without being disorganized and chaotic.

Processing of all sensory information involves complex functions in many different areas of the brain and the integration of visual information with that derived from motor and sensory receptors. Therefore, the quality of an infant's movement necessarily influences acquisition of visual perception (Buktenica 1968).

What happens to the development of visual perception in a child whose postural control and movements are not only delayed, but lack normal quality because of cerebral palsy?

Nathan

At the age of four months, Nathan's general floppiness and crossed eyes concerned his parents (fig. i-3). He was seen by an ophthalmologist who determined that his eyes alternately turned inward (Ness 1980). Two months later, when he still could not hold up his head, did not reach for toys, and could hold objects only if they were placed in his hand, his pediatrician requested occupational therapy developmental evaluation. Nathan was found to be functioning at a three-month to four-month level instead of his chronological age level of six months. A diagnosis was made of hypotonic cerebral palsy and developmental delay.

A preliminary home program was given to the parents. Upon re-evaluation at nine months, Nathan showed increased muscle tone, especially in his arms, and no developmental gains. He was referred to a regional child development team, and comprehensive evaluation at the age of one year revealed a developmental motor level ranging from three months to six months. His visual dysfunction (crossed eyes) was given low priority compared with his severe motor delay.

Fig. i-3

The home occupational therapy program emphasized therapeutic handling techniques during dressing, feeding, lifting, carrying, and playing activities by all family and extended family members. The role of vision in Nathan's sensory and motor development, however, was not specifically addressed at that time.

Development of the Visual Action System

The function of vision is to establish the foundation of sensory information and experience needed to direct movement. The development of human vision is a long and complex process, involving not only the visual organs but also the brain, nerves, and muscles of the entire body. This total action system can be understood only through an appreciation of the progressive, orderly stages of development as the organism reacts to environmental stimuli.

The first, absolute prerequisite for innervation of the eye is light. The newborn reacts to light even through closed lids by flinching or frowning. The mechanism of reflexive constriction and dilation of the pupils (pupillary reactions) gradually matures through the early months of life to allow efficient adaptation of the visual system to different degrees of light.

Early eyelid reflexes include visual responses to sound (cochleo-palpebral), touch (McCarthy's and naso-palpebral), and movement (defensive blink) as well as light (visuo-palpebral). These automatic reactions become integrated with emerging voluntary eye movements. The eyes are rarely idle, especially early in life. They constantly respond to shifts of body posture or initiate the shifts. These movements are seen first in total patterns such as eyes and head moving together for localization of targets. They gradually become more selective as the eyes are able to separate from the head for more rapid and efficient ocular pursuit and gaze shifts. Therefore, the growth of visual functions must be interpreted in terms of a basic motor maturation.

The action system, however, does not grow at a uniform rate. The process of developmental organization resembles an intricate melody with rhythms, accents, pauses, crescendos, and diminuendos, reflecting the patterns of the child's adaptations and spontaneity (Gesell, Ilg, and Bullis 1949).

Cerebral Palsy and Visual Problems

Joseph, Melinda, and Nathan all have cerebral palsy. Joseph, who is moderately involved, uses forearm crutches. His visual pathology interferes with learning in his classroom for the trainable mentally handicapped. Melinda, who walks independently without assistive devices, is considered mildly affected. Her visual perception problems present challenges for academic programming in her classroom for the educable mentally handicapped. Nathan, whose physical handicaps are severe, is at present nonambulatory. His lack of visual-motor control makes special adaptations necessary before he can reach his learning potential in his classroom, where he is integrated with nonhandicapped peers.

Each child has unique visual-motor problems related to total body development; each has compensated with adaptations that may or may not contribute to visual efficiency. This process of individual adaptation to interrupted normal development is illustrated by these three case studies. For each case, the literature is reviewed, models evolved, assessments administered, and management planned with the focus on visual function. To enhance the learning process, comparisons of specific problems, individual styles of adaptations, and intervention modifications are included. In addition, since the developmental process embraces the total life cycle, visual-motor patterns of the mature adult are also examined in the context of functional skills required in the home and community as well as the educational environment.

The Normal Young Adult

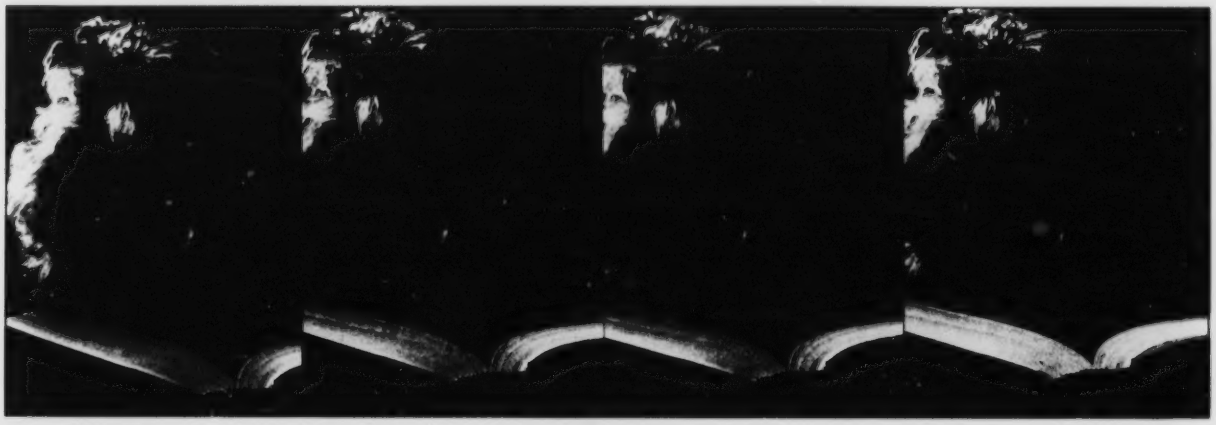
The young adult is observed as she functions in her present environment, that of a college student. Her pupils adjust quickly from the bright morning sunlight on campus to the darker hall of the building she enters.

During a physical education class, a teammate shouts her name from across the basketball court. Her head and eyes turn quickly to localize the sound. The ball is thrown hard and fast, and her eyes converge smoothly as she prepares to catch it. She dribbles toward the basket, using peripheral vision to monitor the movements of the other players as well as her own movement through space.

Driving home after classes, she visually tracks another car approaching the intersection, waiting until it stops before she continues driving.

That evening, sitting comfortably in her apartment, she maintains intense visual fixation as she applies polish to her fingernails.

When she begins to study, accurate and efficient gaze shifts help her easily absorb the contents of the book she is reading for long periods without tiring. In these scanning movements, the eyes move separately from the stationary head, proceeding from left to right, returning to the left, and moving down for the next line of text (figs. i-4 – i-7).



Figs. i-4 – i-7

The Developmental Link to Function

The earliest stage of visual processing can be linked to the global level of motor development. Between birth and two months, the normal infant's posture is disorganized, with reflexive, random eye movements related to reflexive, random body movements. Asymmetry in the eyes as well as the head and limbs appears to allow only monocular fixation in peripheral visual fields. Total rather than discrete eye and hand patterns prevail; thus visual processing is inefficient. Many handicapped children whose motor levels are below two months demonstrate these same visual-motor behaviors. Therapeutic goals are usually aimed at helping these individuals become organized and consistent in their responses.

Between three and six months, the normal infant enters an integrative stage in which head stability and midline orientation accompany symmetrical hand use and binocular vision. Increasing control and coordination of vision and movement is correlated with decreasing reflexive influences. Visual processing improves as behavior becomes more goal directed. Therapy that helps achieve qualitative motor milestones usually includes involvement of the eyes as the orienting and steering mechanisms. Sequences of normal development provide guidelines for planning intervention (Sonksen 1982; Langley, Nelson, and Padula 1986).

A significant stage of maturity in visual-motor function is reached in normal development by six months, when primitive reflexes are integrated and essential eye movement components are nearly as functional as in the adult, except for slight but measurable differences in the latency times between stimulus and response (Parks 1966; Duckman 1988).

From seven months onward, the solid base of motor control provides a foundation for the discriminative stage, when visual perception blossoms. The normal infant explores a wide variety of integrated movement components as experiential learning contributes to depth perception, object permanence, cause and effect, and visual memory. The visual-cognitive system becomes refined in preparation for optimal discriminative visual tasks such as reading (Sonksen 1982; Langley, Nelson, and Padula 1986).

Observing these visual and motor developmental patterns and linking them to functional skills can be useful in making the study of visual development relevant to the problems of children and adults with developmental disabilities such as cerebral palsy (Erhardt 1987a, 1987b).

Assessment and management of these individuals is not a simple process. Information must be gathered from many different sources. Medical data describes the optical and neural systems. Educational assessments and plans state levels of function and specific objectives. Developmental reports of both visual and motor skills provide sequential structures for intervention. All information, however, must be relevant to functional priorities, which are individually determined. The process of discovery is a long one, requiring persistence and dedication by all team members, but when most of the pieces are collected, they begin to fit together, and the picture will emerge.

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PART ONE

Theoretical Rationale

Chapter One
The Medical Model: Joseph

Vision begins with light, the abundant rain of the sun's energy falling through space to touch and warm the earth.
(Wertenbaker 1981, 7)

The medical approach to visual handicaps is based on a model of pathology. In this model, dysfunction can be diagnosed and managed by identifying the etiology of the injury or disease that has caused an interruption of the organism's normal state of health. The assumption is made that skilled visual function depends on an intact anatomical structure and normal physiological processes of the eye, the visual pathways, and the cerebral cortices, and that intervention aims to restore or remediate pathological deviations.

Physiological Anatomy of the Eye

The eye itself is a receptor organ. The act of seeing is the reception of patterns of light, shade, and hue, and the transmission of this sensory information by a physiological process (neuro-electrochemical activity) to the occipital lobes, the vision center of the brain. Seeing depends on the function of organic optical structures. The act of looking is paying attention to what is seen and interpreting its meaning by a psychological process. Looking depends on previous experience, general intelligence, and the state of alertness (Kirk 1981; Sheridan 1979; Getman 1962).

Eyeballs. The eyeballs, or globes, are contained in the bony orbits. The orbits serve as protection and also house the optic nerve, ocular muscles, blood vessels, other nerves, and fat that fills the spaces between the structures. Figure 1-1 shows the eyeball from the side.

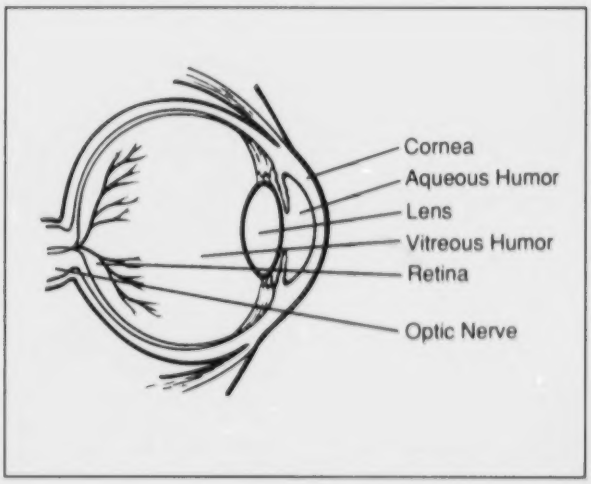


Fig. 1-1
The Eyeball

Cornea. The cornea (window of the eye) is transparent, fibrous, and the most anterior coat of the eyeball. Because it is steeply curved, it performs much of the refraction (bending) of light entering the eye, specifically that which accounts for the coarse, nonvariable focus. Because the cornea cannot change its own curvature, it is limited in the amount of refraction it can accomplish.

Lens. The lens, which is also normally transparent but very flexible, performs the fine variable adjustments of focus as well as the coarse adjustments not made by the cornea. Since it can change its own curvature, it is capable of more refraction than the cornea. Figure 1-2 shows the lens from the front, with the ciliary muscle forming a ring around it and connecting to the lens through the zonule fibers. The ciliary muscle constricts, decreasing the diameter of the ring. This reduces tension on the lens, makes it more convex, and focuses the light closer to the lens (fig. 1-3). Light rays from close objects need to be bent more than those from distant objects in order to focus on the macula, the region of most distinct vision in the retina, which receives the images. This process of accommodation (adjustment of the lens curvature to focus images at different distances), occurs whenever a target is less than 20 feet away (fig. 1-4). Further than that, or when the eyes are at rest, the light rays can focus on the retina without accommodation of the lens.

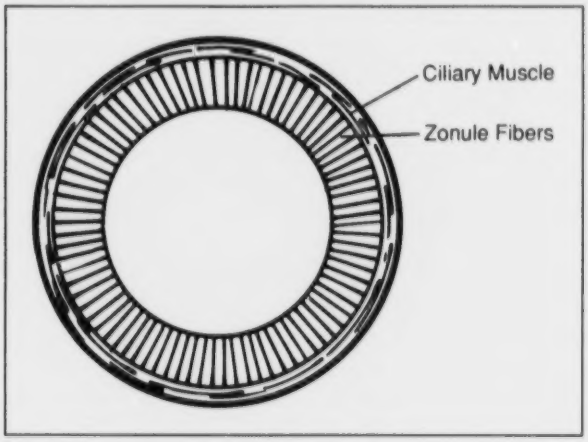


Fig. 1-2
The Lens from the Front

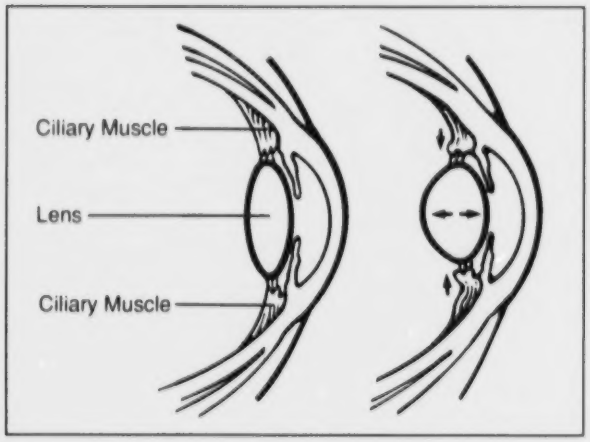


Fig. 1-3
The Lens from the Side

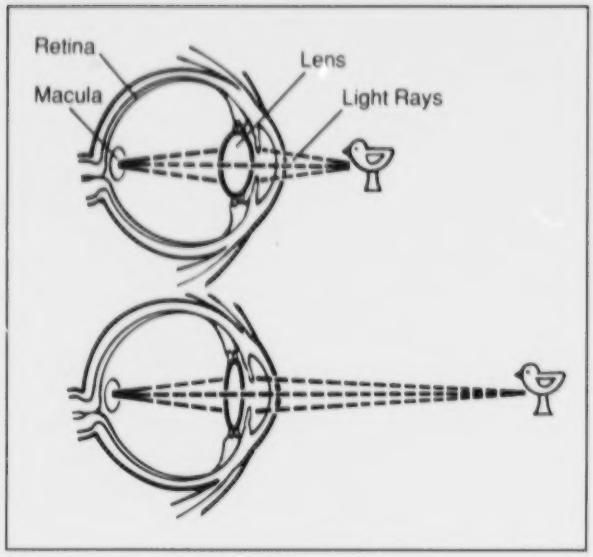


Fig. 1-4
Accommodation of the Lens

Iris and pupil. The muscles of the iris, part of the vascular coat of the eyeball, operate similarly to the muscles surrounding the lens. The iris limits the amount of light by controlling the size of the pupil (aperture, or opening). In bright light the pupil constricts to allow a small amount of light into the eye; in dim light it dilates so that larger amounts can enter. The circular constrictor muscles at the pupillary border contract, decreasing the circumference of the ring, and the pupil becomes smaller. When the radial dilator muscles contract, the circumference increases, and the pupil enlarges (fig. 1-5).

The pupils contract in sleep, more so in deep sleep, and dilate immediately upon awakening, more slowly on gradual awakening. Dilation of the pupils occurs with anxiety, fear, pain, sexual arousal, and certain stages of coma (Peiper 1963; Baird 1983). Pupillary reactions involve direct pathways to the midbrain from the optic tract and are primarily reflexive.

Accommodation, however, involves both pupillary constriction and action of the lens, with a pathway to the visual cortex and back. The cortex must determine that something is out of focus before instructions can be sent to correct that focus. Thus an individual who is totally blind may have pupillary reactions but no accommodation of the lens (Goldberg 1982).

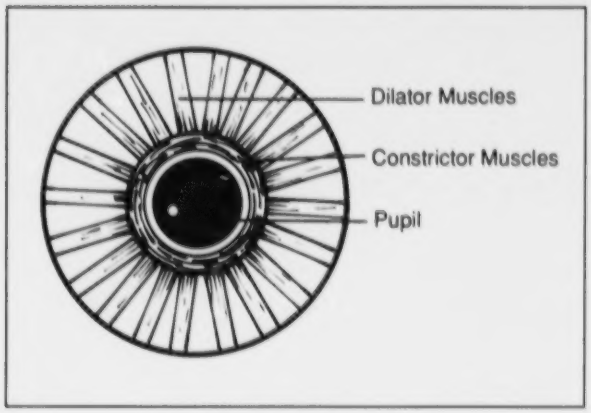


Fig. 1-5
The Iris

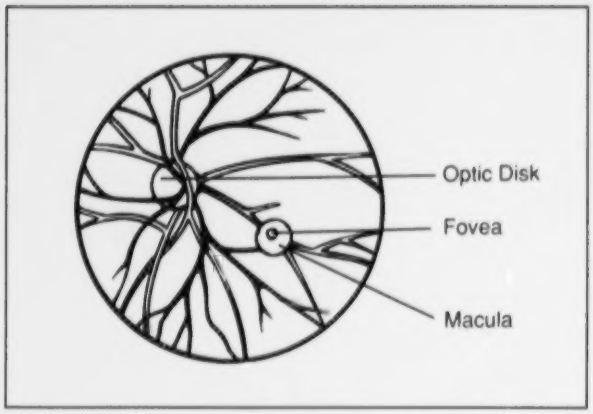


Fig. 1-6
The Retina

Retina. Light passes through the cornea, the anterior chamber of the eye containing aqueous humor, the lens, and the vitreous humor before passing through all the layers of the transparent retina, the innermost neural coat of the eyeball, and striking a layer of photoreceptors. The photoreceptors set up a chain of nerve impulses that are transmitted through the optic nerve to the occipital lobes of the brain (fig. 1-1).

The photoreceptors in the human eye consist of 130 million rods and seven million cones. Controversy exists in the literature concerning the ontogenetic and phylogenetic development of rods and cones, that is, which are more primitive and begin to function earlier (Peiper 1963). Rods are found primarily in the peripheral areas of the retina. They are responsible for awareness of movement and light and are sensitive to low light levels, which makes them effective at night (scotopic vision). Cones, which are found in the central area, provide detail, identification, and color, and function best in bright light (photopic vision).

In the center of the retina is the macula, which houses the highest concentration of cones and provides the best visual acuity, especially for tasks such as reading. In the center of the macula is the fovea, the region of most distinct vision, containing only cones. Approximately three millimeters from the inner side of the macula is the optic disc, where nerve fibers and blood vessels entering and leaving the eye are present. Because no light receptors are present in the disc, it is the only part of the retina where vision is absent and is referred to as the blind spot (fig. 1-6).

Optic nerve. The optic nerves leave the back of each eye and meet at a point called the chiasm, where nasal fibers from the right eye join temporal fibers from the left and proceed to the left side of the brain. In the same manner, nasal fibers from the left eye and temporal fibers from the right eye join together and proceed to the right side of the brain. Thus, nasal fibers cross, whereas temporal fibers do not. The nerves continue to the lateral geniculate bodies, where 80% of the images are directed to the occipital lobe. The visual cortex in this lobe processes information about form, brightness, shape, size, distance, and depth as well as information from other parts of the brain. The act of seeing is accomplished. The other 20% of the messages are directed to areas such as language, which names what is seen, and motor, which controls muscles for eye movements, reaching for what is seen, and so on (fig. 1-7) (Farber 1982; Goldberg 1982).

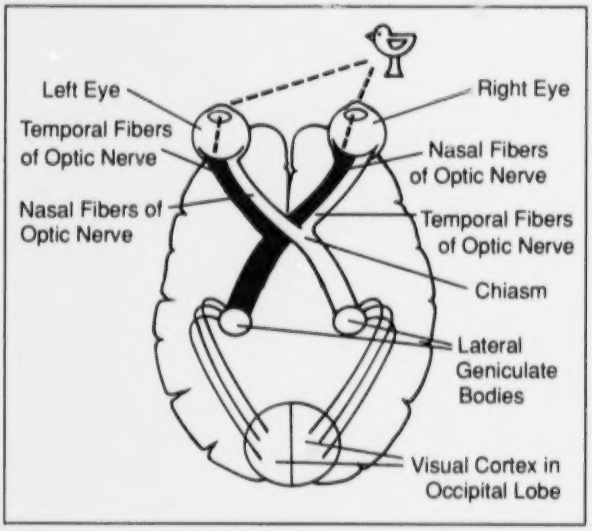


Fig. 1-7
The Optic Nerve

Eyelids. The eyelids protect the eyes from external injury, foreign bodies, and excessive light and exposure, and are under both voluntary and involuntary control. Voluntary closure can be bilateral (blinking) or unilateral (winking). Involuntary movements include the peripherally stimulated reflexive blink and the centrally controlled periodic blink. The periodic blink rests and cleanses the eyes, prevents dizziness, provides protection, and increases visual perception. Each blinking movement lasts several tenths of a second and is accompanied by changes in the illuminance of the retina, disappearance of the retinal image for a period of time, and displacement of the image as the eyes make small rotations and then return to their original position (Yarbus 1967).

The blink rate varies widely in adults and is influenced by emotional states such as anxiety, tension, and preoccupation but not visual fatigue. Contact lens use probably increases the blink rate (McEwen and Goodner 1969). Table 1-1 presents the average frequency of periodic blinks in children and adults. The orbicularis muscles, innervated by cranial nerve VII (facial), close the eyelids, and the levator palpebrae muscles, innervated by cranial nerve III (oculomotor), open them. Because of their proximity and connections to the sensory nerve pathways of cranial nerves V (trigeminal), VIII (auditory), and II (optic), the eyelid reflexes are activated by a wide variety of stimuli, including touch, sound, and light (Goldberg 1982).

TABLE 1-1
Frequency of the Periodic Blink

Age	Average number of blinks per minute
Premature	1
Newborn	1
1 month	1
2-12 months	2
1-2 years	2
3-6 years	4
7-11 years	6
12-16 years	10
17-20 years	19
21-60 years	12

Sources: Peiper 1963; McEwen and Goodner 1969

Extraocular muscles. Six extraocular muscles control movements of each eye. The four rectus muscles are named according to their placement: superior, inferior, medial, and lateral. They come from the apex, or base, of the orbit and insert on the anterior part of the globe. The two oblique muscles insert on the posterior half of the globe. The superior oblique also comes from the apex of the orbit, but the inferior oblique comes from the lower nasal wall (fig. 1-8).

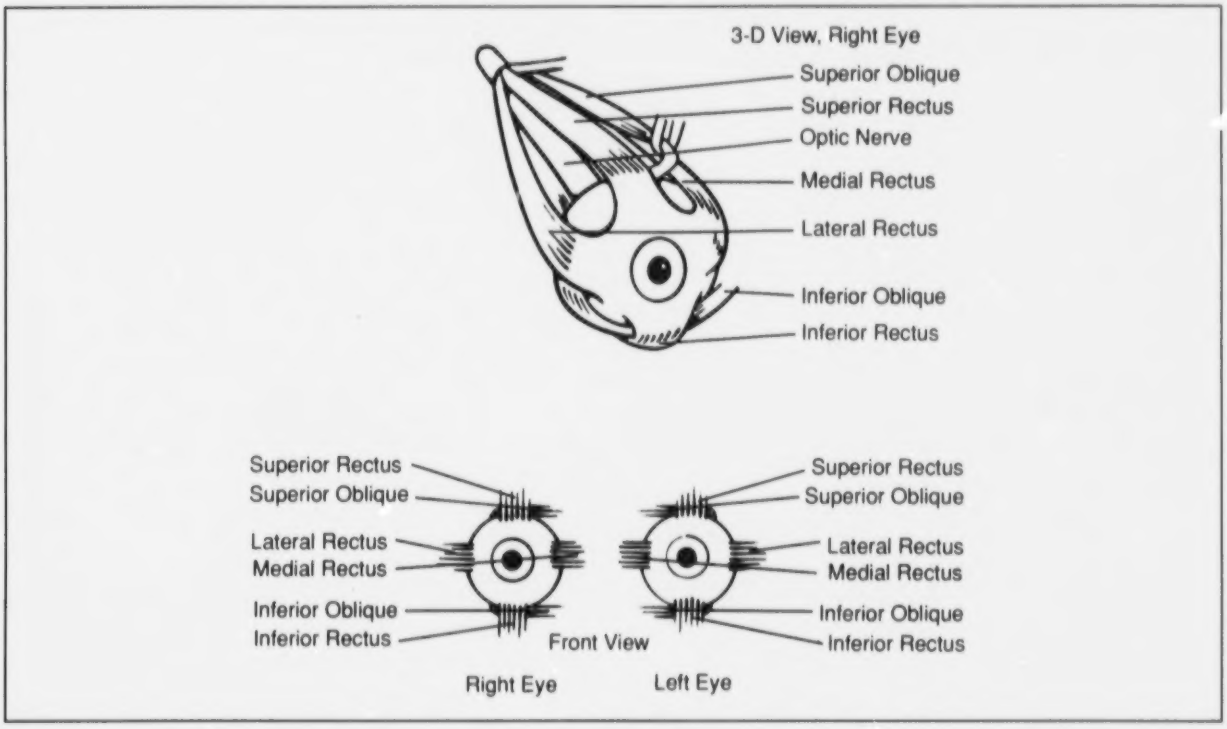


Fig. 1-8
Extraocular Muscles

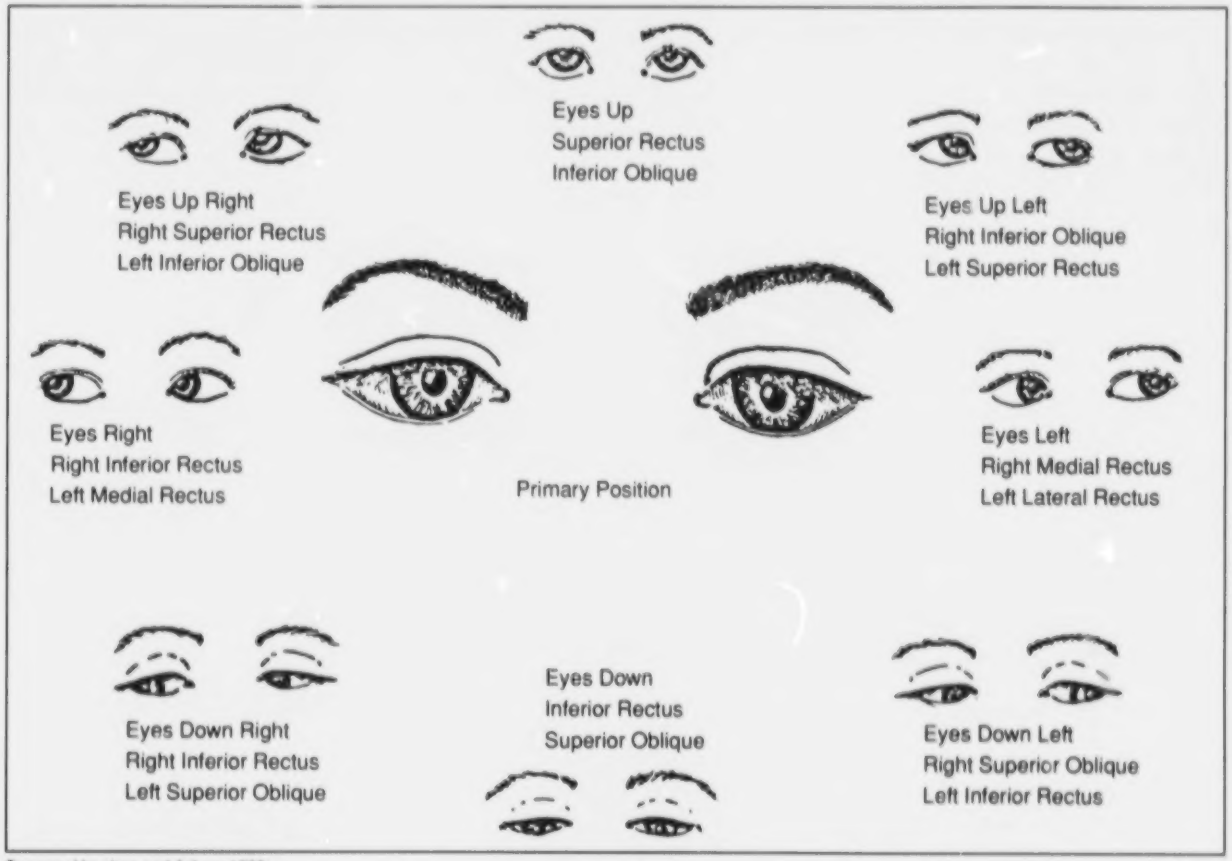
These extraocular muscles, which are innervated by cranial nerves III (oculomotor), IV (trochlear), and VI (abducens), are able to move the eyeball about 45 degrees in any direction except down, in which direction the range of movement increases to 60 degrees. This is helpful because contemporary visual function involves a great deal of gazing downward (Kirk 1981).

In conjugate gaze, a muscle of one eye is paired with a muscle of the opposite eye to produce movement in eight directions: (1) up, (2) down, (3) up and to the right, (4) to the right, (5) down and to the right, (6) down and to the left, (7) to the left, and (8) up and to the left. These paired muscles are termed yoke muscles and receive equal innervation according to Hering's law (Vaughan and Asbury 1980; Baird 1983). Figure 1-9 illustrates the yoke muscle combinations.

The extraocular muscles accomplish convergence by bringing the visual axes of the two eyes together, making a single image from two images. The ciliary muscles change the shape of the lens to accomplish accommodation (focusing). The primarily voluntary movements of the striated extraocular muscles and the primarily involuntary movements of the smooth ciliary muscles are both innervated by cranial nerve III (oculomotor). Convergence and accommodation are normally matched, that is, a target is accommodated at the same distance that the eyes converge upon it (Kirk 1981). As the eyes accommodate on a near fixation point, they converge a fixed amount (accommodative convergence). Each person has a fixed amount of accommodative convergence per unit of accommodation known as the AC/A ratio (Hansen 1988).

Relationship of Optical and Neural Development

The eyes focus light rays on the retina, where they are converted into nerve impulses. The impulses are



Sources: Vaughan and Asbury 1980; Ski-Hi Institute 1983; Baird 1983

Fig. 1-9
Yoke Muscle Combinations

carried by the optic nerves and visual pathways to the occipital cortex, producing the sensation of sight. Vision thus depends on the integrity of the optic structures (the eye itself) and the neural components (pathways and brain).

The rapid changes in visual responsiveness during the first few months of life correspond to the development of the nervous system. The underlying processes involve maturation of visual structures as well as links between the cortical and subcortical structures that relay decisions made in the cortex. These processes are differentiation of the fovea (complete by four months), myelinization of the optic nerve (subcortical pathways set up by three months), and an increase in number, cell size, and interconnectivity of synapses in the striate cortex (during the first six months, with an abrupt increase at two months).

Visual responses of the human infant in the first two months are determined largely by activity in subcortical pathways in addition to some functional links between the eyes and cortex. Cognitive awareness of disparity is necessary before the achievement of voluntary shifts of attention and binocular vision, which requires convergence. Attempts to shift gaze can be seen in head and body movements, but a strong stimulus from another location is required to accomplish visual release of a target (Kirk 1981; Atkinson 1984).

Comparison of the Visual System in Premature and Term Infants

The preterm infant's eyes appear to be too large for the orbits, which grow larger relative to the eyes in the full-term baby. The primitive vascular system, consisting of the hyaloid artery and pupillary membrane, persists in the small premature infant (less than 32 weeks gestation) for several weeks after birth and is usually absorbed before the full-term date has been reached.

The macula is very immature, thicker than the rest of the retina with several layers of ganglion cells, and the fovea is not yet hollowed out. The cones are short and poorly developed, explaining the lack of fixation in the small premature infant at birth. By full term the macula is better developed but not yet in adult form. Ganglion cells have migrated away from the area of the fovea, which has thinned out, thus allowing light more direct access to the cones. The cones gradually become larger and more numerous, until the infant reaches four months and the macula becomes mature.

The lateral geniculate nucleus neurons show immature features such as numerous dendritic and somatic spines. The external surface of the cerebral hemisphere is smooth until five and a half months gestation, when large sulci begin and become deeper, increasing in number until two weeks before term. Evolution of cortical striations begins at six and a half months gestation, with differentiation of cortical layering in the occipital lobe. Synaptic density is still low, gradually increasing in intensity and reaching a maximum at eight months postnatally (van Hof-van Duin and Mohn 1984).

A temporary myopia (nearsightedness), usually disappearing by three months, or rarely, by six months, is common in the small preterm. In contrast, the full-term is usually hyperopic (farsighted) at birth. These refractive differences are related to the variations in the curvature of the cornea and the lens. From an anatomic standpoint, the newborn's eyes are functioning, although incomplete foveal development and accommodative deficiency interfere with adequate focusing on objects (Peiper 1963).

Disagreement has existed in the literature concerning visual acuity in the developing infant, with 20/20 (potential for normal acuity) present at six months according to some authors, but not until four years to five years according to others (Vaughan and Asbury 1980; Batshaw and Perret 1981). The newborn's visual acuity was most commonly reported to be 20/400, improving to 20/100 by six months, when measured by optokinetic nystagmus (OKN) or forced preferential looking methods (PL), but visually evoked potentials (VEP) estimated visual acuity at 20/100 to 20/400 at birth and 20/20 to 20/40, or normal adult acuity, at six months (Morse and Trief 1985; Peckham 1986).

Premature infants tested with the OKN have shown acuity levels as low as 20/800, indicating that improvement is related to gestational age rather than postpartum age. Optokinetic nystagmus (OKN) is the series of eye movements occurring when a succession of objects pass across the visual field. The infant's responses to a striped rotating canopy consist of a slow fixation phase and a fast corrective phase in the opposite direction. The smallest stripe

width determines the measure of visual acuity that is evaluated by an observer. Advantages are that OKN is an involuntary process, can be used with infants only a few hours old, and is low cost. Disadvantages are the difficulty in maintaining infant fixation on the stimulus and in gaining a high degree of objectivity in observer evaluation. Most studies use video or film cameras because of the difficulty of observation, especially in newborns. Also, a cortically visually impaired child may test as having vision because the response is subcortical. Thus, the clinical use of OKN may be misleading.

Preferential looking (PL) is based on the assumption that an infant will fixate on a patterned rather than a homogenous field. PL presents the infant with choices of a series of black and white stripes and a plain gray screen, matched for average brightness. The number and duration of fixations are recorded and interpreted by an observer looking at the corneal reflection over the pupils through a peephole centered between the two targets and recording the duration of fixation on each stimulus. An advantage of PL is that the techniques are simple, needing little instrumentation or training. The primary disadvantage is that it requires an alert and cooperative child.

Visually evoked potential (VEP) is an objective, noninvasive technique that evaluates visual function through the electrical activity of the visual cortex in the occipital lobe, produced in response to a visual stimulus. Electrodes are placed on the scalp, and the signals are amplified and recorded to produce an encephalogram (brain-wave pattern). Advantages of flash VEPs are that direct evaluation of the visual sensory system is not dependent on motor responses, requires no overt behavioral response, and is fully objective. Pattern VEPs require a child to cooperate, that is, attend, fixate, and accommodate to the target. Disadvantages are the need for complicated, expensive equipment, the skill needed to develop and interpret the data, and the absence of clinical norms (Morse and Trief 1985; Fagan and Shepherd 1986).

Optic nerve tracts and pathways are not myelinated at the time of birth or before. Thus eye movements during the term infant's first few days (and a few weeks later in the preterm) are mediated by nuclear, or reflex, centers. For example, the newborn fails to blink in response to the approach of a threat, despite intact orbicularis muscles, demonstrated by reflex blinking to tactile stimulation near the eyes. The process of myelination is greatly accelerated immediately after birth, and voluntary eye movements then involve more complex neural pathways. The afferent (sensory) pathway includes retina, optic nerve and tracts, lateral geniculate body, and occipital cortex. The efferent (motor) pathway includes the occipital cortex, cranial and oculomotor nerves, and eyelid and extraocular muscles. The apparent increase of eye incoordination during the next month or two represents the period of transition from one type of neural organization (reflexive or involuntary) to another (cortical or voluntary).

When born between 28 weeks and 32 weeks, the very small premature infant's eyes remain closed for the first week or two after birth. No attempt is made to fixate on light. In fact, avoidance of bright light may occur. Between two weeks and six weeks after birth (well before the full-term date), the eyes begin to open.

Born between 32 weeks and 36 weeks, the baby will respond to light and will show more dislike for very bright light directed into the eyes. The eyes will open in two weeks or three weeks, before the full-term date. A fleeting, crude fixation on a large dangling object is possible in the first two weeks of life of a 36-week infant.

The full-term infant may keep the eyes closed for a few hours or a few days after birth. Crude monocular fixation and tracking are possible in a very limited arc. Some photophobia is present. During the first month, only large objects in near space are visible to the normal infant (Brown 1961; McGraw 1969).

During the process of developing a neurological assessment of newborns that was appropriate for preterm as well as full-term infants, Dubowitz and Dubowitz (1981) found, contrary to findings published by other authors, that environmental factors such as low ambient lighting positively influenced visual development in preterm infants who displayed significant tracking skills. These environmental factors raised the preterm infants' level of development higher than that of newborn term infants. Their conclusion was that intense and continuous bright lighting in many newborn units may depress and delay normal visual maturation. Appropriate light exposure appears to hasten the rate of myelinization. Thus, a normal preterm baby, when reaching expected delivery date, will have more advanced myelinization than a normal newborn term infant.

However, most studies show that during the first year, the visual development of normal preterm infants is related to conceptional or corrected age rather than postnatal or uncorrected age, with no indication of either delayed or accelerated development (Hoyt, Nickel, and Billson 1982).

Effects of Prematurity on Visual Function

A variety of visual impairments are common in premature infants with low birth weights. The increasing survival rate, due to technological advances in neonatal care, has been accompanied by an increase in handicapping conditions.

ROP. In the late 1940s and early 1950s retrolental fibroplasia (RLF) was a significant cause of blindness in premature infants. The condition has been renamed retinopathy of prematurity (ROP). The association between oxygen and RLF was unknown until 1953, and many children were treated with 100% oxygen for respiratory distress during the first few weeks of life. The high concentration of oxygen destroyed the network of rapidly growing blood vessels in the retina. When the infants were returned to regular room air, new capillary growth was accompanied by scar tissue that contracted, detaching the retina (Batshaw and Perret 1981).

Despite monitoring of oxygen levels in incubators to reduce the incidence of retinopathy of prematurity, a new group of ROP children is appearing in infants born at very early gestation stages.

Effects of the NICU environment. Many preterm infants undergo intensive medical and surgical interventions, with life sustained by mechanical support systems. Hospitalization is often prolonged to gain physiological stability and nutritional growth, with detrimental effects on motor, perceptual, language, and emotional development. The neonatal intensive care unit environment provides varied, inconsistent, and sometimes inappropriate patterns of stimulation that may be detrimental to sensorimotor integration.

The preterm infant's tactile experience is often unpleasant and painful because of blood tests, intravenous tubes, and other procedures that cause withdrawal and distress. Reduced tone, restraints, and seizure medications may decrease movement and tactile exploration. Although human voices are obscured unless directed through the incubator doors, levels of auditory stimulation, especially from the sound of mechanical equipment, are excessively high, penetrating the incubator. Sudden sounds of doors slamming have been observed to coincide with startle responses in the infant. Vestibular stimulation may also be reduced due to static positioning and decreased holding and rocking during the acute phase of care (Anderson 1986). Visual stimulation differs significantly from that in a home environment because of the intense and continuous bright ambient lighting common in the neonatal intensive care unit. Even full-term newborns are so sensitive to light that they do not open their eyes fully and consistently for the first few weeks. Prolonged avoidance may depress and delay normal visual maturation. The etiology of permanent photophobia following neonatal asphyxia may be cerebral or retinal (Jan et al. 1987).

Multiple handicaps. Studies conducted in the 1960s and 1970s indicated growing numbers of visually impaired children with multiple handicaps, for example, children who were deaf-blind and had cerebral palsy. Genetically determined conditions included congenital optic atrophy, cataracts, and diabetic retinopathy. Prenatal infectious diseases such as cytomegalic inclusion virus (CIV), fetal toxoplasmosis, and maternal venereal conditions also contributed to the population of visually impaired with additional handicaps.

Research is only beginning on the increasing population of babies and children with AIDS, HIV infection, and who are drug-exposed, but deficits in visually directed grasp, eye-hand coordination, and visual perception have already been identified (Weston et al. 1989; Anderson et al. 1990).

In 1976 the World Health Organization named four factors placing children at risk for developing visual impairments:

1. Prematurity
2. Family history
3. Intrauterine infection
4. Difficult labor

Recent studies of defective visual development in low-birth-weight infants question whether retinal imperfection is as great a contributing factor as other cerebral dysfunctions associated with prolonged or difficult labor and resultant anoxia (Fledelius 1981; Gates 1985; Morse and Trief 1985).

Cerebral palsy. The incidence of serious problems in newborn infants is about one in 100. Developmental disabilities can result from hundreds of malformations, diseases, and injuries to the brain. The causes of cerebral palsy, which is defined as a disorder of movement and posture resulting from a nonprogressive abnormality of the immature brain, are identifiable in only 60% of the cases. Of those identified, approximately 40% result from events during the prenatal period, 20% during labor and delivery, and 40% from complications in the postnatal period, including those associated with prematurity (Hagberg 1979).

Types of cerebral palsy have traditionally been classified according to muscle tone and movement: spasticity, athetosis, flaccidity, ataxia, rigidity, tremor, and mixed. Classification has also been made according to the body parts affected: diplegia, hemiplegia, quadriplegia, and more rarely, triplegia and paraplegia.

Children with spastic or pyramidal cerebral palsy have suffered damage to the motor cortex or pathways. In the premature infant, a fragile area exists at the upper part of the precentral gyrus (motor strip) in the frontal lobe. If hypoxia or anoxia occurs because of respiratory distress, this part of the brain is the first to experience damage, and control of primarily the lower extremities (diplegia) is affected. If a lesion occurs in one side of the cortex, the opposite side of the body will become more spastic (hemiplegia). Quadriplegia is the term used when a large part of the cortex is severely affected, and all four limbs suffer varying degrees of spasticity (Batshaw and Perret 1981).

Visual defects and cerebral palsy. A significantly higher incidence of visual anomalies exists in children with cerebral palsy than in the normal population. Several reviews of the literature found motility defects and refractive errors to be the most common. Problems with motility, or oculomotor dysfunction, include strabismus with lack of fusion, irregular eye movements in following moving objects, and nystagmus. Approximately 5% of all children have some form of strabismus, but the percentage in children with cerebral palsy is reported to be anywhere from 30% to 60%. Refractive errors are found in 30% of normal children, compared with 30% to 60% in those with cerebral palsy. Other frequent visual defects include amblyopia (2% in normal, 20% to 30% in children with cerebral palsy), accommodative insufficiency, retinal abnormalities, and optic atrophy with field losses (Batshaw and Perret 1981; Harley and Altmeyer 1982; Kirk 1981; Morse and Trief 1985; Duckman 1979, 1984).

Refractive errors. When rays of light pass obliquely from a transparent medium into another of different optical density, they are bent or deflected. The bending is called refraction. Emmetropia is the condition in which an eye has no refractive error. Incoming parallel light rays are focused on the retina without the assistance of accommodation. Because measurements of the eye in the normal population vary as much as height and weight do, emmetropia is rare.

Ametropia means the eye has a refractive error. Decreased visual acuity can be caused by refractive or nonrefractive problems. Refractive errors can usually be corrected with prescriptive lenses. If the focal point of the image falls in front of the retina, the condition is called myopia (nearsightedness). If the focal point falls behind the retina, hyperopia (farsightedness) is the result. Astigmatism is caused by a cornea that is irregularly shaped or conical rather than curved. All three conditions may cause a blurred image. However, the younger the otherwise normal farsighted child is, the more easily the child can accommodate to clear the defocused image. Adults who are farsighted (presbyopia) have lost the ability to accommodate because of increasing inflexibility of the lens. A concave or minus lens is prescribed for myopia, a convex or plus lens for hyperopia, and a cylindrical or spherocylindrical lens for astigmatism. Bifocals contain a convex lens to help the presbyopic eye focus for reading at near point (fig. 1-10).

The strength of a lens refers to its refractive power. The unit of measurement is expressed by the diopter, the power that will bring parallel light rays to a focus at one meter. The stronger the refractive power of a lens, the closer its focal point is. The diopter (D) is defined as the reciprocal of the focal length in meters. Thus, for example, a 2.00 D lens will have a focal length of one-half meter, and a 4.00 D lens will have a focal length of one-fourth meter. Fractional powers are always expressed with one figure before the decimal point and two decimal places after, for example, 0.25. Convex lenses are designated as plus because they have the power to produce a focus; concave lenses are designated minus because they

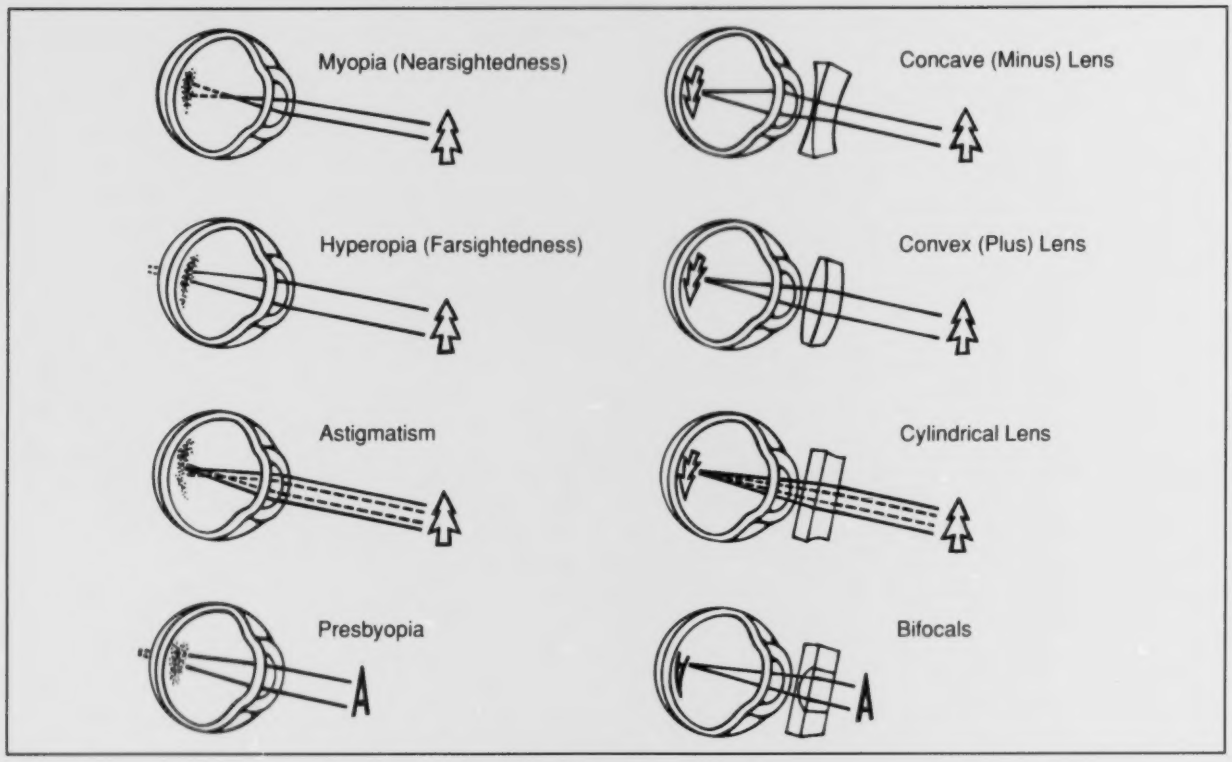


Fig. 1-10
Refractive Errors and Lens Prescriptions

have only imaginary focusing power and are important in compensating for excessive convergence (Kirk 1981; Goldberg 1982; Goble 1984).

Normal vision is defined as 20/20. The numerator equals the distance at which the measurement is taken. The denominator equals the distance at which the normal eye can see a specific image. The definition of legal blindness in most states is visual acuity of less than 20/200 or a visual field of less than 20 degrees, with correction. A person with low vision is one with acuity ranging from 20/70 to 20/200 with correction. The incidence of blindness in children is one out of 2500, with 46% of those born blind and 38% more losing their sight before age one (National Library Service for the Blind and Physically Handicapped 1988).

Strabismus. Binocular vision, the fusion of two separately perceived images, depends on the coordinated movement of both eyes. Binocularity depends on normal retinal correspondence (NRC), the unified perception of a target as the foveae of the two eyes have common lines of direction.

Strabismus is defined as the inability of the two eyes to direct gaze simultaneously at the same target for binocular fixation because of an ocular muscle imbalance. If the image falls on the fovea of one eye but not on the other, fusion is disrupted (abnormal or anomalous retinal correspondence, or ARC).

To avoid diplopia (double vision, or more accurately, overlapping images), the brain suppresses one of the images, risking amblyopia (lazy eye) and reduced visual acuity in the disused eye if the strabismus is constant and not alternating. Vision is usually suppressed in the eye that requires the most focusing effort. For example, in a patient with anisometropia (mismatched optics) of +2.00 diopters and +5.00 diopters, the latter will be more likely to deviate because of suppression.

Strabismus is classified by the direction of the deviating eye. Esotropia, or convergent strabismus, is the most common, with the eye turning nasally (inward). In exotropia, or divergent strabismus, the eye turns temporally (outward). Vertical deviations usually are designated according to the eye that turns

upward (hypertropia). A common unit for measuring strabismus is the prism diopter (P.D.). Alternating or intermittent tropias are less likely to cause amblyopia because each eye is used part of the time (Vaughan and Asbury 1980; Kirk 1981; Goldberg 1982; Hansen 1988).

The purpose of strabismus therapy is to obtain good vision in each eye, to have two cosmetically straight eyes, and to gain binocular vision with fusion and stereopsis. Methods include occlusion of the straight eye to force use of the crossed eye; refractive lenses, which may include bifocal adds and/or prisms; orthoptics (visual exercises) to improve both monocular and binocular vision; and surgery to straighten the crossed eye.

The length and intervals of patching regimes depend on the age of the child and whether the strabismus is constant or intermittent. Occlusive therapy is usually used in conjunction with one or more of the other treatment methods (Kirk 1981).

The effects of extraocular insufficiency can be neutralized by the use of prisms. A prism is a solid wedge-shaped piece of glass or plastic that displaces the direction in which light rays enter the eye. The deviation is at both the surface of entrance and the surface of exit (fig. 1-11). The position of a prism when placed in a lens for glasses is indicated by the direction of its base, which can be in, out, up, or down. The total amount of prism is usually divided between the two eyes to avoid a lopsided pair of glasses, even if one eye is better than the other.

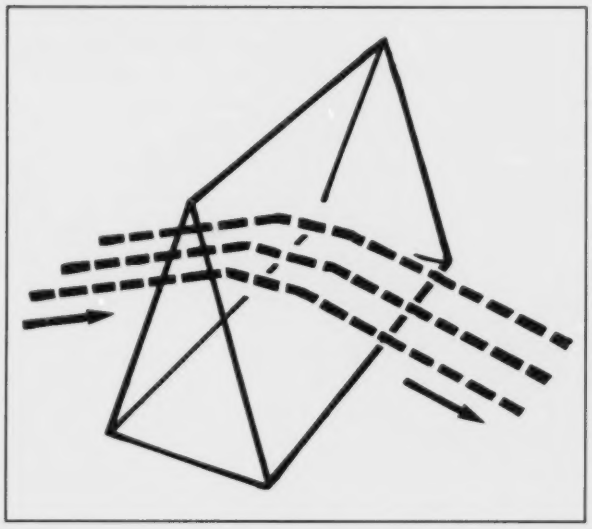


Fig. 1-11
Prism Refracting Light Rays Toward the Base

Prisms can decrease the need for compensatory head postures by shifting the visual field more to midline (Kirk 1981; Goble 1984).

The efficacy of visual training and its correlation with improved reading and learning skills has been the subject of vigorous controversy. The ophthalmological profession has viewed reading problems to be the *cause* of irregular eye movements rather than the *effect*, whereas orthoptists and optometrists (developmental, behavioral, and functional) support links between specific eye exercises and increased academic performance (Ludlam 1961; Greenspan 1976; Helvesten 1978; Atzmon 1985; Duckman 1987; Ludlam and Ludlam 1988).

Since eye muscles are innervated equally, weakness of a muscle in one eye stimulates increased innervation of the corresponding muscle in the other eye, which overacts and pulls it too far in one direction. Also, because the eye muscles work in pairs within each eye, weakness in a muscle affects its antagonist, again interfering with alignment of the eyeball. The objective of surgery may be to restore fusion, improve cosmesis, and increase ocular movement. The position of the eye may be altered by moving the muscle insertions appropriately backward or forward. Procedures include recessions, myotomies, or resections. In esotropia, the medial rectus may be moved backward to weaken its pull, and the lateral rectus may also be moved forward to strengthen it. In exotropia, the lateral rectus muscle is weakened, while the medial rectus is strengthened. Weakening procedures generally work better than strengthening procedures (Kirk 1981; Hansen 1988).

Amblyopia. The two main causes of amblyopia are strabismus and a significant discrepancy of visual acuity between the eyes. Both causes are associated with a lack of binocular vision and fusion. The definition of amblyopia (lazy eye) is reduced visual acuity not correctable by refractive lens. As already stated, in the case of strabismus, the brain ignores one of the double or overlapping images and thus does not use one eye. In the case of anisometropia (when refractive error in one eye differs markedly from that in the other), fusion cannot occur, even when the eyes are correctly aligned, and only one image is transmitted to the brain. Early treatment (before age seven) has traditionally been considered necessary to prevent the condition from becoming irreversible (Vaughan and Asbury 1980; Goldberg 1982).

Nystagmus. Certain involuntary movements of the eyeball are termed nystagmoid and are associated with decreased visual acuity. Rhythmic nystagmus is characterized by alternate slow and quick components and repeated, jerky movements. Nonrhythmic or pendular nystagmus consists of fairly regular and equal to-and-fro movements. Nystagmus is also classified in terms of direction: horizontal, vertical, oblique, rotatory, or mixed. It varies according to speed (between 10 and 100 oscillations per minute), as well as to amplitude, defined as coarse if excursions are more than three millimeters and fine if less than one millimeter. Congenital nystagmus has been associated with more than 40 birth defects but may not be apparent until two months or three months of age. It is pendular at rest, changing to rhythmical upon lateral gaze. Nystagmus is caused by pathological factors governing the ocular subsystems and their central and peripheral connections, including the occipital cortex, postcentral gyrus of the parietal lobe, and the midbrain. It may be minimal in one position, and the baby may adapt by tilting the head very early in life. Children and adults with nystagmus find a "null" point where the nystagmus is minimal or "dampened" in order to accomplish close tasks such as reading. Many individuals with low vision adjust to their nystagmus and do much better than expected from their visual acuity test. They need relief, however, from doing close work for long periods of time, since they fatigue quickly and can read efficiently for short periods only (Arnott 1976; Kirk 1981; Baird 1983).

Optic nerve and visual field loss. Damage to the occipital lobe or to various parts of the visual pathway (cortical tracts, optic chiasm, optic nerve, or retina) results in different kinds of vision loss. For example, a lesion in the left occipital lobe results in a right hemianopsia, and the person will be blind to objects in part or all of the right visual field (fig. 1-12, example illustrated in c). Homonymous hemianopsia has been found in 25% of children with cerebral palsy (Goble 1984; Goldberg 1982; Moore 1988).

The visual status of children with optic nerve atrophy is not easily determined. They may have some central vision; peripheral vision may be so poor that they are unable to find nearby objects without searching with their hands (Kirk 1981). The severely constricted peripheral fields of children with cerebral hypoxia have been linked to specific hypoxic-ischemic brain damage (van Hof-van Duin and Mohn 1984; Jan et al. 1987).

Intracranial hemorrhage. One of the major causes of brain damage or death in newborns is intracranial hemorrhage, which may result from trauma, lack of oxygen, or sudden changes in blood pressure. A small amount of bleeding is common, especially in preterm infants, without long-term consequences, but large hemorrhages due to compression of blood vessels, impaired circulation, and inadequate blood supply often lead to cerebral palsy. Intraventricular hemorrhage is a common event in premature infants, whose vessels are fragile and susceptible to

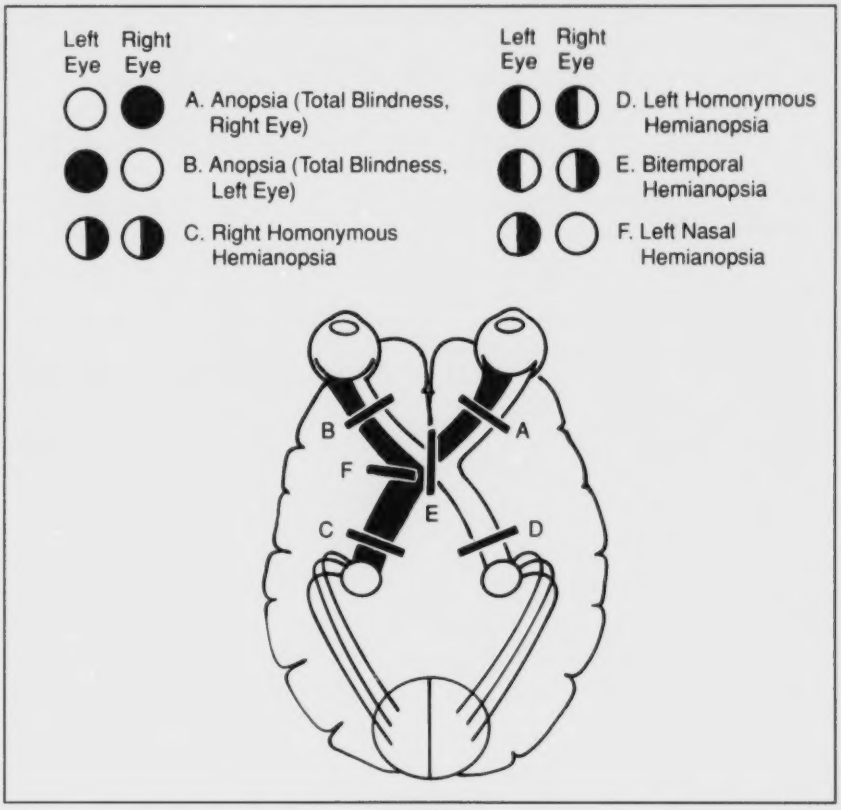


Fig. 1-12
Examples of Visual Field Deficits

perforation. During respiratory distress the blood count drops, seizures may begin, and bleeding into the ventricles occurs. The hemorrhages may be severe enough to cause enlargement of the ventricles or bleeding into the brain substance with permanent destruction and cyst formation.

A study of 100 infants consecutively admitted to the neonatal unit at Hammersmith Hospital in London, England, during a nine-month period included a large percentage with intraventricular hemorrhage (IVH). Between 27 weeks and 31 weeks gestation age, approximately 70% of the infants had IVH. Between 32 weeks and 35 weeks, the percentage dropped to about 30%, and after 36 weeks to 8%. Visual tracking was absent in 75% of the infants with IVH, irrespective of their maturity, compared with 15% without IVH. There was also a very high correlation between the presence of hemorrhage and the development of roving eye movements in infants under 35 weeks. Another observation was that recovery of infants with IVH followed a consistent pattern. Limb tone, motility, and visual tracking improved long before trunk tone and head control (Dubowitz and Dubowitz 1981).

Seizures. The pupils may be fixed and dilated, or involuntary eye movements may occur in many types of seizures. A frontal lobe lesion may cause the head and eyes to turn to the side opposite the lesion. Occipital lesions are commonly manifested by unformed visual hallucinations in the contralateral half field, followed by a major seizure. During generalized seizures, the eyes usually deviate upward. Visual stimuli such as blinking lights or even television may trigger seizure activity (Meadows 1976; Baird 1983).

Children whose seizures are regulated by medication may also experience drug-induced ocular side effects. For example, phenobarbital and its derivatives control seizures by depressing the central nervous system and can weaken eyelid muscles, influence pupil size, and cause photophobia or hippus (continual constriction and dilation of the pupil). Phenobarbital can also affect extraocular muscles, increasing random eye movements, jerky pursuits, and convergence difficulties. Tegretol® (carbamazepine) has been known to cause double or blurred vision. Dilantin® (phenytoin) may decrease convergence skills as well as accommodation (focusing) or increase esotropia (Fraunfelder 1976; Gole 1988). The more time required to achieve seizure control, the greater the dosage and the more types of anticonvulsant drugs needed, the more unlikely a positive prognosis (Batshaw and Perret 1981; Blackman 1986).

Status epilepticus, a series of convulsions lasting more than an hour, may be dangerous because of prolonged depletion of oxygen to the brain. Valium® (diazepam/Roche), the current medication of choice, is given rectally or intravenously and usually stops the episode within 10 minutes. The goal of anticonvulsant therapy is to reduce the frequency and severity of seizures so that they do not seriously interfere with everyday function, since complete suppression may not be possible.

Hydrocephalus. Another frequent complication of brain damage associated with IVH and prematurity is hydrocephalus, an imbalance between secretion and absorption of the cerebrospinal fluid. This fluid flows through the four ventricles within the brain and surrounds the spinal cord. If the flow is obstructed at any point, it backs up in the ventricles and leads to increased pressure inside the brain and against the bones of the skull. In an infant, the increased pressure causes the head to enlarge since the bones are not yet fused at the sutures. The forehead may bulge, with the skin stretched tightly, and the veins in the scalp become prominent. The setting-sun phenomenon, a persistent turning down of the eyes, is often a diagnostic feature of hydrocephalus.

About half of all hydrocephalus conditions are caused by inflammation from bleeding or hemorrhage into the ventricles. Treatment usually involves the surgical placement of a bypass to allow the fluid to flow from the ventricles into another part of the body where it can be absorbed. A ventriculoperitoneal shunt conducts the cerebrospinal fluid into the abdominal cavity, decreasing intracranial pressure, and preventing further enlargement of the head (Batshaw and Perret 1981). A malfunctioning shunt, however, is one of the causes of seizures, which are common in children with cerebral palsy, and as previously stated, require medications that have significant ocular side effects. Thus fluctuations or inconsistencies in visual function may be related to shunt malfunctions, developing seizure activity, or toxic drug levels.

The strabismus that often occurs with hydrocephalus may be either an esotropia (inward eye turning)

or exotropia (outward eye turning). Esotropic strabismus is likely to occur because the sixth cranial nerve runs a longer, more exposed course intracranially than the third or fourth and thus is more susceptible to injury with a rise in intracranial pressure. Exotropia is rarely the result of hydrocephalus affecting the third cranial nerve. More often it is related to optic atrophy produced by the dilatation of the third ventricle, causing pressure on the optic chiasm (Wybar 1976).

Cataracts. Developmental cataracts occur congenitally or during early life as a result of genetic, nutritional, or inflammatory disturbances. The lens becomes increasingly opaque, with a gradual loss of visual acuity, as the cataract increases in size.

Visual processing deficits. According to the territoriality concept of neuroplasticity, if early in life a lesion destroys a vital area of the cortex in one hemisphere such as Broca's expressive language, a very similar area in the other hemisphere apparently assumes those functional tasks. However, the crowding of an extra function into a different part of the brain may limit the potential of the original genetically programmed function. Territorial deficits may be manifested behaviorally and psychologically, especially if the child is unable to compensate or adapt easily to changing environmental demands. In mature brains, following a lesion in one hemisphere, the other hemisphere may not be able to take over the lost function because territories have already been committed. Some lost function may be regained if other cortical areas of the same hemisphere are reorganized, but the degree of plasticity is much less in adults than in children. Right hemisphere lesions, especially in males, are usually more severe than left and thus show a poorer functional recovery (Moore 1988).

Joseph

Joseph was born ten weeks prematurely, and weighed 1.3 kilograms or 2 lbs. 15 oz. He displayed the significant respiratory problems that are common in preterm infants and then suffered a severe intraventricular hemorrhage, which resulted in a massive left parietal/occipital porencephalic cyst, hydrocephalus, and a seizure disorder. The hydrocephalus, which causes a phenomenon termed sunset eyes, was managed with a ventriculoperitoneal shunt and required numerous revisions because of malfunctions (fig. 1-13). A diagnosis was made of spastic quadriplegia, right more involved than left.

Fig. 1-13

By six months, when the normal baby's eyes are moving together symmetrically, Joseph's did not. Shortly afterwards, an ophthalmologist began following him regularly because of "abnormal eye movements"and reported that at 18 months Joseph showed strabismus (inability of the two eyes to direct gaze simultaneously to the same target because of an ocular imbalance) with esotropia (inward turning of the right eye) as well as retinal abnormalities, scattered pigmentation in the right eye, and a possible abnormal optic nerve head in the left eye (fig. 1-14).

Fig. 1-14

An examination at age two and a half revealed continued dysconjugate eye movements (eyes not moving together), a variable esotropia, and a right hypertropia (upward deviation of the right eye), demonstrated in figure 1-15 (Joseph sitting on his grandfather's lap). He was given prescription glasses because of a high myopia (nearsightedness) in both eyes. When Joseph was five, surgery was performed to decrease the strabismus and improve muscle balance. It included recession of the right medial rectus and resection of the right lateral rectus. New observations at his

Fig. 1-15

next ophthalmologic examination at nine included a small cataract in the right eye; pendular nystagmus (involuntary, oscillatory movements of the eyeballs) decreasing the level of functional vision; astigmatism (a refractive error caused by unequal degrees of refractive power in the cornea's various meridia, but corrected with the myopia by the prescriptive lenses); and a right eye significantly smaller than the left, with its vision probably suppressed by the brain (fig. 1-16) (Sorgen 1975-1983).

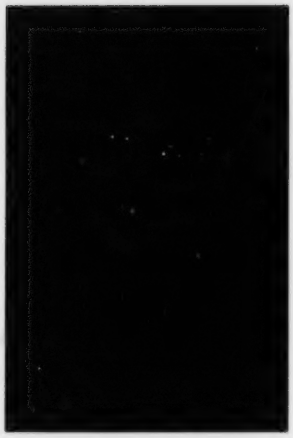


Fig. 1-16

Joseph's seizure activity, which began when he was two days old, has varied considerably during his 11½ years. Shunt malfunction usually increased the frequency and severity, with associated irritability. His seizures most often began on the left side of the face and hand, spread toward the left, and were marked by his eyes rolling back and forth, rapid breathing, and arm and leg jerks. For a number of years he was seizure-free. However, he began to show a definite cycle of increasing behavioral problems, including hyperactivity, restlessness, irritability, sleep disturbances, and increased urination, culminating in a seizure, followed by improvement, before the approximately six-week cycle was repeated. Several times a year Joseph was subject to focal status seizures, which were effectively stopped with Valium® (diazepam/Roche) administered rectally. By age nine, attempts to control his seizures with different medications had not been totally successful. For example, at times toxic side effects from Dilantin® (phenytoin) had produced balance and vision problems, and it was unclear what proportion of the behavioral problems of irritability and tantrums were due to the side effects of medication or directly to the cycling seizure pattern. He eventually improved somewhat on a combination of Mebaral® (methobarbital) and Tegretol® (carbamazepine) and was able to maintain more manageable behavior within his seizure cycle, so his seizure disorder was not considered to be a major contributing factor to his learning problems.

According to neuropsychological testing, Joseph's pattern of brain damage was diffuse, severe, and significantly worse in the left hemisphere. Many of his left hemisphere skills have been redistributed in the brain, crowding multiple functions into the right hemisphere. As a result, he does not show the usual left hemisphere language disorders (language functions are preserved), but he has severe loss of abstract verbal and sequential reasoning and some impairment of visual-spatial thinking. However, despite Joseph's significant vision loss and poor eye-muscle control, visual processing in his brain is more efficient than any other sensory modality. In other words, Joseph is a visual learner with multiple visual handicaps.

Recommendations of the neuropsychologist were to (1) make sure visual information enters his system, utilizing optic means (corrective and prism lenses) and educational adaptations (whole-word approach rather than phonics and special body/materials positioning), and (2) improve eye-motor and eye-hand control, allowing greater access to his preserved visual information processing capacity (Fisher 1987).

Theoretical Bases for Intervention

Animal studies, particularly of kittens, have determined critical periods during which blurred vision or deprived visual stimulation causes permanent visual defects (Wiesel and Hubel 1963; Awaya et al. 1973). The concept of sensitive periods in animals and people may offer a basis for clinical management of childhood visual problems if these problems can be identified when changes in environmental factors could modify physiological activity (Ingram 1979).

Treatable pathology has been investigated by those involved in screening and evaluating the visual impairments of premature infants and children with cerebral palsy and other multiple handicaps (Morse and Trief 1985; Harley and Altmeyer 1982; Gates 1985). The primary purpose of early screening is the detection of potentially damaging conditions for which successful therapeutic interventions may be possible. Early attention to cataracts, strabismus, and amblyopia has resulted in effective medical remediation. Until the 1970s, attention to refractive problems had not been given until school age

because of the lack of objective and reproducible acuity testing in infants and young children. Newer testing methods (for example, preferential looking and visually evoked potentials) have provided much more accurate and detailed information.

Transient and permanent cortical visual impairment (CVI), formerly termed cortical blindness because it was always considered permanent, has been found to be more common than previously thought, especially in children with multiple handicaps related to associated neurological problems such as cerebral palsy, mental retardation, epilepsy, hydrocephalus, spina bifida, and learning difficulties. Jan et al. (1987) found behavioral characteristics of these children to include the following:

1. low vision, with variable and inconsistent performance, influenced by fatigue, distractibility, medication, and/or seizures
2. better vision in familiar environments, when the children know on what and where to fixate
3. use of touch to identify objects
4. identification of color stronger than perception of form
5. difficulty with visual-spatial perception
6. poor head control correlated with poor vision

Children with cortical visual impairment have demonstrated traces of vision that can often be recruited to functional levels. The neurological rationale supporting the value of intervention is based on animal research and also on increasing knowledge of nervous system components differentiated as genetically endowed (hard-wired) and environmentally driven (soft-wired). The hard-wired system is experience expectant, needing certain stimuli at certain times to develop normally. The soft-wired system needs and wants change, both novel and complex, tending to habituate and close down without new sensory input.

Physiological and structural changes in maturing infants that illustrate the plasticity of the nervous system include the following:

1. enlargement of the dendritic fields, improved by challenges related to survival (with corresponding shrinkage of the dendritic field in cats during sensory deprivation)
2. increase in the number and strength of synapses, if repetition is novel, not boring
3. increase in the speed of conduction and the number of transmitters across the synapses

It is hypothesized that cortically impaired children beginning to see are experiencing axonal sprouting into damaged areas of the brain. Therefore, intervention can be successful (facilitate higher level function) if activities have the following characteristics:

1. are appropriate to developmental sequences, according to individual needs
2. are goal oriented, purposeful, and meaningful, with active participation
3. are repetitive, yet ever changing to require adaptive responses (Moore 1988)

Eye disorders not remediable by medical intervention can also benefit from early diagnosis because educational intervention may prevent developmental lags caused by visual impairment (Morse and Trief 1985). Suspected visual impairment has been one of the criteria developed for including high-risk infants in tracking systems for continuous monitoring and assessment, leading to referrals to appropriate services (Blackman 1986).

Even before the passage of Public Law 99-457, a team approach to organizing services for young children with special needs was gaining support among early intervention professionals. The idea of identifying the entire spectrum of needs, setting goals, and developing service plans was based on the assumption that all aspects of a child's development are interrelated (Spencer and Coye 1988; McGonigel and Garland 1988). Yet, as children with significant developmental disabilities grew older, the complexity of their multiple handicaps, especially those with a variety of visual impairments, caused difficulties in planning effective and appropriate programs.

According to a survey of multiply handicapped, visually impaired school-aged children in an 11-state Midwest area, services to this population have been at a rudimentary stage. Emphasis has been on either academically oriented services for blind or low-vision individuals, with teachers untrained for those with multiple handicaps, or services for deaf/blind severely/profoundly handicapped children

who function at low developmental levels that do not require academic programs. The large diversified group of less severe multiply handicapped (visually impaired plus learning disabled, educable mentally handicapped, emotionally disturbed, or physically handicapped) have not been effectively served. Part of the problem lies in the variability of current statistical reporting systems, which require reporting on the basis of primary disability and in one category only. Thus many visually impaired children are included in categories of multiply handicapped or mentally handicapped, and many multiply handicapped may be reported as visually impaired only, if that is considered their primary disability. Professionals planning services for visually handicapped persons are not always aware of their other disabilities, and even when additional services are provided, they are often separate rather than integrated with visual services (Gates 1985).

Joseph

Although Joseph's medical history included a variety of serious problems, including inconsistent shunt function, seizures, and abnormal eye movements, his motor delays were a major concern. Joseph did not roll over, sit alone, or crawl at age one, when other children were learning to walk, and he did not use his right hand.

When ten months of conventional range-of-motion exercises prescribed by a physiatrist during Joseph's second year did not result in significant improvement, his mother asked the family pediatrician for referral to a nonprofit mobile occupational therapy program. At age two, the preliminary home program was implemented by Joseph's mother and supervised by the author's weekly visits. It emphasized rolling, sitting balance (fig. 1-17), bilateral arm use in play activities with his sister (fig. 1-18), and unilateral use of the right hand as well as continued range-of-motion exercises for the arms and legs. After several months of interruptions because of two hospitalizations for shunt revisions, the program was resumed, with a home health aide as the primary facilitator three times weekly, supervised once or twice a month by the registered occupational therapist. Activities added after evaluation of reflexive and postural motor control, hand function, and feeding skills included sensory stimulation, specific grasp and release, dressing and feeding activities, transitional movements, and supported standing (fig. 1-19).

Fig. 1-17

Fig. 1-18

Fig. 1-19

At age three, Joseph was evaluated with the Gesell Developmental Schedules, which identified certain areas of visual dysfunction within adaptive, motor, language, and personal-social domains. Incorpora-

tion of visual awareness into therapeutic activities was accomplished with finger/penlight tracking, eye-hand pursuit of paper airplanes or balloons, and exploration of visually stimulating materials such as a magnifying glass and a kaleidoscope, as well as many prewriting activities.

Joseph's home program continued until he entered school. His home health aide continued working with him under the occupational therapist's supervision, eventually accepting employment as his full-time classroom and therapy aide.

A comprehensive evaluation including ophthalmological and educational reports at age five and a half revealed the following information about Joseph's visual status, with some implications for educational programming:

The left eye was more functional than the right, but showed a definite esotropia (inward turning), especially when tired. Visual acuity was estimated at 20/200 *with* corrective lenses. A mild nystagmus decreased when the glasses were worn. The left eye used a 90-degree visual field, 45 degrees on either side of midpoint. The right eye used only 45 degrees on the left side of midpoint. Therefore, Joseph exhibited a partial right hemianopsia (inability to use the right side of the right eye's visual field). He also preferred the lower quadrants of both eyes. He appeared to compensate by tilting his head to the left, which was actually a way to rotate the field of vision to a more horizontal orientation (Fisher 1987). Optimal vision (and the best null point for his nystagmus) appeared to be at six inches, although discrimination of one-inch figures was possible at 12 inches. Tracking also was accomplished most effectively with the left eye at six inches (Gaudry 1980).

According to the summary report, Joseph showed potential for better utilization of his vision.

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Chapter Two
The Educational Model: Melinda

It is . . . the nature of man that he wishes to define what he sees and to understand why he sees what he does.
(Arnheim 1974, 8)

Occupational therapists have traditionally been involved with the evaluation and treatment of children with eye-hand coordination problems that have interfered with their educational process in the school setting and the attainment of their independence in daily living activities.

In 1978, the American Occupational Therapy Association (AOTA) was awarded grant funding by the Department of Education, Office of Special Education and Rehabilitation Services, for a three-year period to develop a competency-based in-service training program entitled "Training: Occupational Therapy Educational Management in Schools" (TOTEMS). According to the final report on the project, "The primary goal for occupational therapy education related services was to enhance the learning potential for handicapped students and to facilitate a student's adaptation to his educational environment" (Gilfoyle and Hays 1981, 2-3). Approximately 2000 therapists completed the training, with an estimated impact upon 200,000 handicapped students. In a pre-project survey, one of the ten most critical tasks identified by occupational therapists was implementation of activities to improve visual-motor skills, ranked sixth in frequency and third in value (Gilfoyle and Hays 1979).

In 1986 AOTA's Representative Assembly voted to adopt a position paper entitled "The Roles and Functions of Occupational Therapy in Early Childhood Intervention" (replaced in 1988 by "Occupational Therapy Services in Early Intervention and Preschool Services"), which delineated assessment areas of "gross-motor development, fine-motor and object-manipulative skills, sensory integrative and perceptual processes, *functional use of vision*, oral motor function, communication, social interaction, and self-care abilities" (italics added). Included as an example of individual program implementation was the provision of "activities combined with physical handling and positioning techniques to facilitate the child's development of higher level skills, such as postural control, *visually directed reach*, grasp, manipulation of objects, and motor development" (italics added). Another position paper, "Occupational Therapy Provision for Persons with Learning Disabilities and /or Mild to Moderate Perceptual and Motor Deficits," includes concerns about visual-spatial perception, visual distractibility, and organization of basic sensations (movement, touch, and vision) (AOTA 1986, 836, 837; AOTA 1988a, 1988b).

Vision and Learning

The relationship between vision and learning has been difficult to understand, partly because of the way the medical model defines vision and simplistically describes it primarily in terms of only one of its attributes, contour resolution (the identification of form outline). Visual defects are usually grouped under several classifications:

Refractive status: myopia, hyperopia, astigmatism

Tissue loss from disease or trauma: retinitis pigmentosa, retinal hemorrhaging due to diabetes, optic atrophy due to wounds of the eyeball, optic tract, or visual cortex

Temporary tissue dysfunction: inflammation, contusions, or hysterical conditions

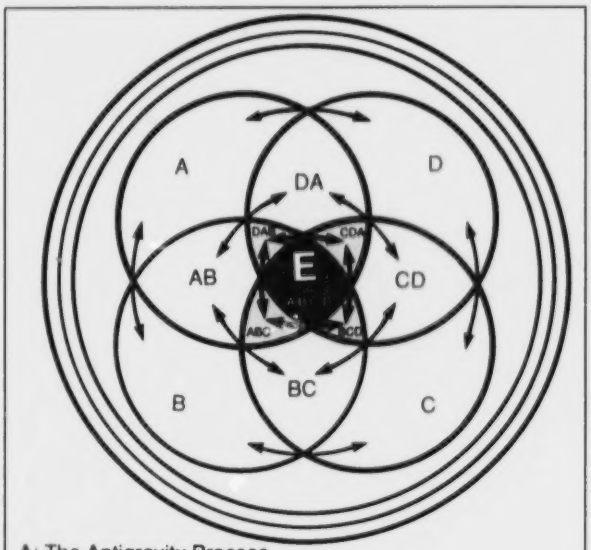
These defects are seen as malfunctions primarily reducing visual acuity, with standard procedures for recognition and remediation (if possible) of the conditions through lenses, surgery, patch programs, and/or medication. According to developmental optometrists, this approach is self-limiting in that other aspects of vision and its influence on learning are not considered.

An alternative point of view considers vision to be the result of the integration of many subskills. The individual responds to and processes the information contained in the light energy entering the eyes against a background of information received by all other sensory systems, as well as past experiences (Schrock 1978).

Skeffington's Model of Vision

A broader view of vision was emphasized by Skeffington, a pioneer optometrist who developed a cyclic, not sequential, model of vision illustrating the complexity of the organism. Figure 2-1 presents Skeffington's model of vision, adapted from Schrock (1978). In this model, vision emerges from four subsystems, processes in an expanding spiral:

1. The antigravity process: development of the neuromuscular system toward stability (erect balance) and mobility (movement through space), orientation with the environment through integration of vestibular-kinesthetic-proprioceptive-visual sensory information
2. The centering process: utilization of information from many sources to localize objects in space in relation to the self
3. The identification process: matching and categorizing of current and past visual experiences, leading to abstract thinking
4. The speech-audition process: communicating information through labeling, and matching vision with language to code, store, and retrieve past experiences (Lesser 1966; Schrock 1978)



Source: Schrock 1978

Fig. 2-1

The Visual Processes (Skeffington's Model of Vision)

The Antigravity Process

Gross-motor, fine-motor, and visual-motor patterns of the normal newborn are all influenced by the prevailing uterine physiological flexion posture. This passive posture helps keep the baby "collected," integrating the very primitive central nervous system. The predominance of flexor tone at the natal stage of development provides proximal stability in the head and shoulder area, important for visual distal mobility. The flexion posture decreases as random distal movements inhibit muscle tone, increase muscle elongation, and provide sensorimotor experience for improved active muscle control. This developmental process is illustrated in Table 2-1. The normal infant's progress, during the first six months, from the supine and prone positions to sitting and standing is linked with observable visual behaviors at the same age levels.

TABLE 2-1
Relationship of Gross-Motor and Visual Development During the Antigravity Process

Age	Development: Gross Motor	Development: Visual
Natal		
Supine	Physiological flexion, primarily proximal; total flexion and extension patterns with distal random head and limb movements	Eyes move together with head; eyes yoked together during random eye movements; easily distracted by targets in periphery; crude monocular fixation; irregular tracking of targets through 45 degrees in preferred peripheral field
Prone	Center of gravity on chin and shoulders (influenced by flexed pelvis); asymmetrical neck extension used to lift head to clear air passages	
Supported sitting	Head flops forward into gravity; rounded back	
Supported standing	Legs flexed, no weight bearing; primary standing and automatic stepping reactions with total support	
1 Month		
Supine	Physiological flexion inhibited by more random movements; beginning ATNR helps head turn toward hand	Head and eyes turn toward diffuse light; fixation on hand or agitated target in line of vision only within 10"; jerky, slow tracking from periphery to midline and back to side; alternating monocular fixation
Prone	Center of gravity on chest as less pelvic flexion allows more posterior weight shift; more head rotation and momentary extension to shoulder level	
Supported sitting	Head still sags, back rounded into gravity	
Supported standing	Hips still flexed with more external rotation and abduction; some passive weight bearing with maximal support	
2 Months		
Supine	Hypotonic, more extension and abduction of limbs; asymmetrical neck flexion, full head rotation, brief head in midline	Head and eyes turn to target in peripheral field; sustained fixation on hand in ATNR position; beginning binocular fixation with overconvergence; tracking slightly past midline with head rotation; poor regulation of eye speed to target speed; eyes lose ability to move together as voluntary gaze shifts begin; beginning vertical tracking
Prone	Center of gravity on arms and chest; ATNR used for stability, as head lifts 30 degrees	
Supported sitting	With trunk supported, head bobbingly erect against gravity	
Supported standing	Head intermittently erect as body is supported; hips less flexed; more externally rotated and abducted, little weight bearing	
3 Months		
Supine	Midline orientation and symmetry; head in midline, hands clasping forward against gravity	Prompt midline regard; localizes and watches own hand spontaneously; improved binocular fixation; tracking through 180 degrees, eyes and head together; improved convergence; eyes moving together more consistently; shifts glance between two targets
Prone	Head more in midline and up 45 degrees as center of gravity moves from chest to abdomen	
Supported sitting	With moderate support, leans forward; head control against gravity begins	
Supported standing	Head more erect; more weight bearing with more leg extension and less abduction and external rotation	

TABLE 2-1 Cont'd.
Relationship of Gross Motor and Visual Development During the Antigravity Process

Age	Development: Gross Motor	Development: Visual
4 Months		
Supine	Strong symmetry, midline head control; antigravity flexion (hands to knees, together in space, and bilateral reaching)	Visually directed reach and grasp; localizes targets moving into upper, lower, left, and right fields; improved binocular fixation in middle and far space; prolonged fixation on targets in near space; eyes begin to move independently from head; tracking smooth except for midline jerk; eyes moving together consistently; shifts gaze in different focal lengths; begins to scan three or more targets; losing fixation, relocalizing; visual but not prehensile pursuit of lost target
Prone	Controlled flexion and extension against gravity; head up 90 degrees and sustained; center of gravity on chest and abdomen during weight bearing on forearms	
Supported sitting	Head steady and set forward with minimal support; more trunk control with shoulder retraction	
Supported standing	More weight bearing with arms held; flexes legs down into gravity for stability	
5 Months		
Supine	Increased antigravity flexion (hands bring feet to mouth), beginning rolling moves toward target outside reach	Prehensile as well as visual pursuit of lost target; improved horizontal, vertical, and circular tracking; shifts gaze in same focal length easily; improved scanning of three or more targets
Prone	Center of gravity on abdomen while weight bearing on extended arms with head hyperextension; lateral weight shifting on chest while reaching with one arm	
Supported sitting	Better head control with some hyperextension and stable shoulders with minimal support	
Supported standing	Weight bearing with legs abducted and externally rotated, hands held	
6 Months		
Supine	Independent head lift; rolls	Adjusts body position to localize target visually; eyes move independently from head; eyes move to extreme right and left fields; consistent binocular fixation and convergence at all focal lengths; intense fixation on small as well as large targets; accurate and consistent tracking in all directions, with midline pause during diagonal; shifts gaze easily to scan several targets; shifts gaze easily from one focal length to another; prolonged adaptive interaction of eyes, hands, and mouth
Prone	Center of gravity on abdomen while weight bearing on extended arms with good head control; lateral weight shift on forearms while reaching with one arm	
Supported sitting	Perfect head control; straight back; erect in chair or with arms propped	
Supported standing	Full weight bearing with active hip extension and feet aligned	

Sources: Alexander, Cupps, and Haebig 1980; Blackwell, Britz, and Rock 1983; Erhardt 1982

Melinda

Melinda was a full-term infant, delivered without complications, with a birth weight of 5 lbs. By the time she was three months old, her mother began to sense that she was slower than her older brother had been, but she thought it was because of her small size. Her brother had been able to sit alone when he was six months old and walk at ten months. At her one-year checkup with the family pediatrician, Melinda was still unable to sit alone. Her mother had tried to help her, but stated that "her legs wouldn't go in the right place, her hips were too tight, and her back was round." The pediatrician expressed surprise that Melinda could not even roll over, told her mother that the child was mentally retarded and asked her to bring the child back in a year.

During the next year, Melinda learned to sit alone (in the W-sitting position), pull up to stand, and walk around furniture. For her two-year checkup, her mother decided to take her to a different pediatrician, who noted spasticity in the lower extremities and referred her immediately to a public health nurse who was a specialist in infant development. The parents were given suggestions for balance and eye-hand coordination activities and within two months were able to report observable progress in those areas.

Evaluation. Melinda was then evaluated at a regional child development center by a psychologist and speech pathologist. At 26 months she had a wide scatter of responses to testing, from 12 months in expressive speech and eye-hand coordination to 25 months in receptive language. She was extremely responsive to the examiner's face and verbal directions. A report containing recommendations for speech therapy, occupational therapy, and continuation of the infant stimulation home program was sent to her parents, pediatrician, the county nursing service, superintendent of public schools, director of the rural special education cooperative, and a nonprofit agency mobile therapy unit, which provided occupational therapy and a swimming program staffed by parents and volunteers. Although school services at that time were not mandatory for children under four years in her state of residence, the special education cooperative held a staffing of the appropriate public and private agencies to coordinate Melinda's program.

The county infant-stimulation program, using a home teacher, evaluated and planned intervention in cognitive, fine-motor, and social areas of development, all of which required the integration of visual components. The public schools provided speech therapy. Melinda entered the swimming program and received occupational therapy, with gross-motor development as the first priority. At a chronological age of two and a half years, her developmental motor age was 12 months to 15 months, more than a year's delay, and the quality of her postures and movements was in danger of compromising future development.

The relationship of gross-motor and visual development. Figures 2-2 through 2-8 show the relationship of Melinda's gross-motor development and her visual patterns in a variety of antigravity positions: supine, prone, sitting, and standing.

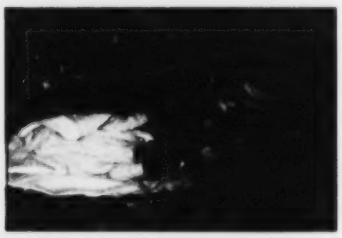


Fig. 2-2

Supine. As a newborn lying next to her brother (fig. 2-2), Melinda displayed normal physiological flexion with distal extension (fingers), and head to the side. Her eyes, linked with the head, attended to the periphery, with one eye open and the other closed (crude monocular fixation).

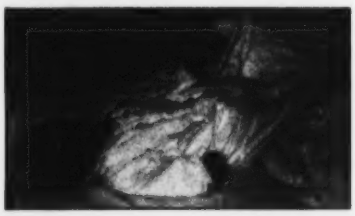


Fig. 2-3

Figure 2-3, at two and a half months, shows a beginning delay as well as postural exaggeration affecting the quality of movement. Instead of becoming more hypotonic and developing asymmetrical neck *flexion*, Melinda's tone has increased, and her asymmetrical neck *extension* includes excessive extension of the jaw as well as eye muscles. These early primitive patterns, including asymmetry of the eyes, were prolonged instead of being replaced by more mature patterns such as head in midline, chin tuck, and eyes moving together and independently of the head. Melinda appeared satisfied to remain in the supine position for extended periods of time, unlike most infants over six months, who prefer the greater mobility and variety of movement that playing in prone allows.

Prone. Figure 2-4, at four and a half months, shows Melinda's head control below the three-month level. Her anterior/posterior center of gravity is at her chest rather than at her abdomen, and she lacks controlled flexion/extension of the head and trunk.

Fig. 2-4

Midline eye and head control is not established, preventing the normal four-month visual skills of fairly smooth tracking and gaze shifts of targets in the same and different focal lengths.

Fig. 2-5

Figure 2-5, at eight and a half months, shows continued delay of gross-motor development, as Melinda demonstrates a typical prone position of the five-month-old, on extended arms with more midline control, shifting of the center of gravity posteriorly, and reciprocal co-contraction of anterior/posterior neck and trunk muscles. Missing, however, are typical eighth-month patterns of crawling on hands and knees, and rotation into sitting.

Supported sitting. Melinda's inadequate head control is clearly demonstrated in Figure 2-6 (18 months) in independent W-sitting. Jaw extension still accompanies neck extension, but her eyes can now move independently from her head in a downward gaze.

Fig. 2-6

Supported standing. Figure 2-7, at eight months, demonstrates fair head control when trunk and pelvis are stabilized against her father's hand and shoulder. In figure 2-8, at three years, despite increased balance that allows her to reach with one hand while stabilizing with the other, her stereotypic eye and head patterns persist.

Fig. 2-7

Fig. 2-8

Occupational therapy program. During the first year of therapy, emphasis was placed on helping Melinda continue through the anti-gravity process with as normal patterns of movement as possible. Techniques such as tapping and pushing, and equipment such as rocker boards and carpeted barrels, were used to stimulate righting and equilibrium reactions in supine, prone, sitting, kneeling, and finally standing (fig. 2-9). Protective extension reactions of the arms improved steadily, ensuring safe falling as well as facilitating a normal pattern of reaching with extended elbows, wrists, and fingers. Walking sidewards along walls (cruising) encouraged normal weight shifting and activated hip abductors but needed careful attention to prevent toe walking because of increased tone in the lower extremities. Heel cords were elongated by passive mobilization and with the help of gravity as Melinda leaned forward to stand with her hands flat on the wall and her feet stabilized flat on the floor. Functional recreational activities included riding a tricycle with adapted pedals and swimming independently in the water with flotation devices.

Fig. 2-9

Re-evaluation. When Melinda was three and a half years old she was re-evaluated at the child development center. An ophthalmology report diagnosing esotropia (inward turning of the eyes) was shared

with the team (Colliton 1976). Progress was reported to be significant, with gains in cognitive, communicative, social, and motor development. Expressive speech had increased, but articulation errors reflected immature patterns and incoordination of the speech musculature, including tongue extension substituting for upward movement. Again, a wide scatter of responses in the cognitive area showed above-age-level skills in language-related tasks such as opposite analogies and picture naming, while difficulties in fine-motor and visual-motor areas and visual perception interfered with task completion. Recommendations included eye surgery to correct strabismus and continuation of all programs, with emphasis on improving visual perception.

The Process of Total Ability Development

Getman described the developmental processes of childhood in a series of six sequential and interrelated areas, each incorporating visual activities that serve to integrate the experiences in a process of total ability development. Although described separately for convenience, they are continuous throughout childhood. In Table 2-2 these processes are arranged chronologically and described.

Visualization, according to Barsch (1968), is the most economic, flexible, expansive, and swift mode for processing information. All other sensory modes contribute to its development, and it enriches the functional efficiency of all others. What in earlier experiences had to be physically present to be touched, tasted, smelled, heard, or seen, eventually can be conjured up by a sequence of graphic symbols arranged on a printed page. Thus, the individual's task is to observe, organize, visualize, and express the terrain of cognitive space.

Skeffington's model of vision (fig. 2-1) proceeded from the antigravity process to centering, identification, and speech-audition, which are all concerned with perceptual processing. Figure 2-10 presents another model of information processing that matches the input-output procedure with the motor, language, and visual perception areas (Hainesworth and Siqueland 1969).

From a medical perspective, the process of visual perception begins with the transmission of the image of an outside object from the retina (containing light-sensitive nerve fibers), throught the optic nerve to Brodmann's area 17, the visual cortex, in the occipital lobe. Areas 18 and 19, which surround the visual cortex, are concerned with visual memory patterns, and communicate with the angular gyrus in the parietal lobe, where the stimulus is interpreted and differentiated. The final transmission of the visually derived nerve impulse is directed to the frontal lobe, where conceptual knowledge of recognition and understanding is located (Goble 1984).

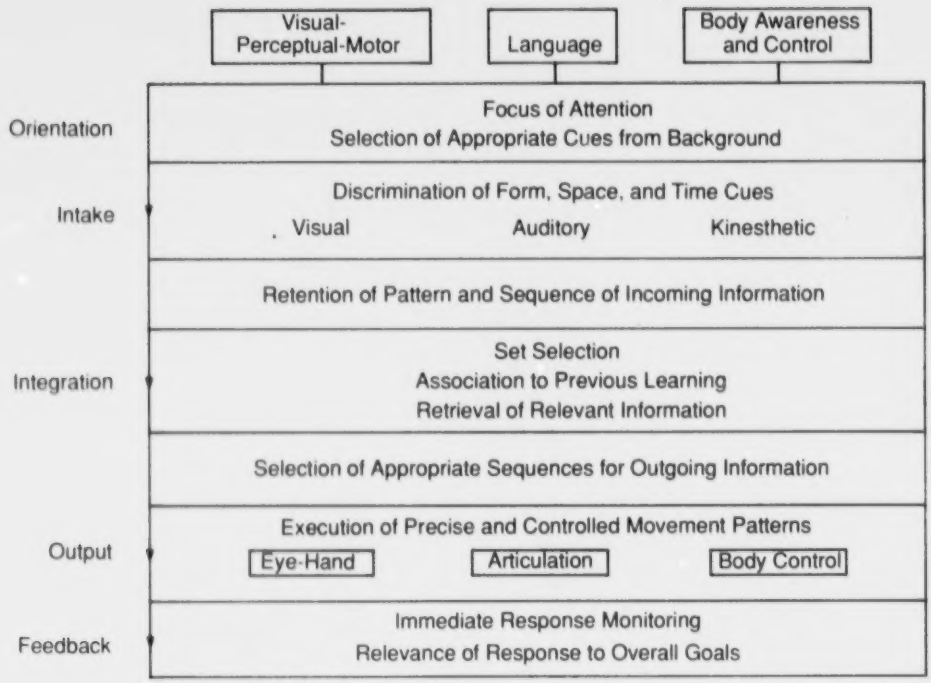
TABLE 2-2
Developmental Processes of Childhood

Process	Description
1. General movement patterns for action	primary process of moving; using eyes as steering mechanism to guide movement
2. Special movement patterns for action	extension of primary process; learning to use body parts singly and in unison for purposeful and skilled movements, particularly eye-hand patterns that integrate vision
3. Eye movement patterns to reduce action	vision replaces some movements as eyes can obtain information without exploration and manipulation
4. Communication patterns to replace action	previous visual and movement experiences used to communicate with others; speech used to verify visual discrimination
5. Visualization patterns to substitute for action, speech, and time	visual interpretation of objects and words allows further knowledge of the environment from the printed page; visual memory depends on visualization and use of symbols, permitting anticipation and planning of future action
6. Visual perceptual organization	ultimate process in development of intellectual capabilities; the end result of the sequential and interwoven relationships of previous processes: ability to interpret, understand, and respond to abstract concepts

Source: Getman 1962

Perceptual Problems

Although the most significant difficulties with visual-motor skills have been observed in children with physical handicaps, more subtle but still pervasive soft neurological signs have been apparent in children with perceptual-motor dysfunctions (Jan, Freeman, and Scott 1977). In addition to fine-motor clumsiness and irregular visual tracking, many of these children displayed behavioral problems of



Source: Hainesworth and Siqueland 1969

Fig. 2-10
An Information Processing Model

hyperactivity and impulsivity and were easily distracted. Children with these behavioral problems often responded positively to structured training programs (Kephart 1960; Getman 1962; Silberberg and Leslie 1968; Huizinga and Smalligan 1968; Erhardt 1971; Swanson 1972; Knickerbocker 1980).

Despite the absence of diagnosed visual-acuity deficits in these children, many of their problems, which interfered with classroom performance, had elements that appeared visually related. The behaviors included blinking, eye rubbing, or frowning while reading or writing; head tilting; placing head close to desk, or head turning to use one eye only; closing or covering one eye; and skipping words, rereading, or using a finger to keep place while reading.

Many professionals recognized the presence of perceptual problems in children with cerebral palsy, despite the tendency for them to be overshadowed by the more obvious physical defects (Crowther 1963; Fenn 1965; Horowitz 1967; Brereton, Sattler, and Ironside 1967; Mayberry and Gilligan 1985), and in children with mental retardation (Haring and Stables 1966).

A general overview of perceptual-motor dysfunction presented at the University of North Dakota in May 1967 included recognition and discussion of a variety of groups with then-undefined perceptual problems: children with cerebral palsy, adults with strokes, and individuals with mental retardation, emotional disturbances, and traumatic accidents (Koehler 1967). Attempts to define and diagnose the problem focused on its etiology, pathology, or its effect on function, particularly learning.

The Controversy of Labels

A great deal of controversy regarding diagnosis (labeling) and management (both medical and educational) has surrounded the syndrome alternately described in the last 25 years as brain damage, neurological impairment, educational handicap, minimal brain dysfunction, dyslexia, perceptual handicap, and learning disability with associated problems of visual perception and processing (Buktenica 1976).

Perhaps one of the earliest terms, "brain damage," described by Straus and Lehtinen in 1947, had the

disadvantages of implying an etiology that could not be confirmed as well as an assumption of previous intactness.

The term "neurological impairment," adopted by the California Association for Neurologically Handicapped Children, was fairly widely used in the United States during the 1950s and early 1960s. It avoided the problem of etiology, but was considered too general, since children with cerebral palsy and other syndromes could be included.

In 1963, in consideration of the state board of education's need for an operational definition, the California state legislature adopted the term "educationally handicapped" to include children with neurological or emotional handicaps or a combination of both (Mahler 1966). In the same year, at a meeting of the International Study Group in England, the term "minimal cerebral dysfunction" was recommended (MacKeith and Bax 1963). The term "dyslexia" was coined by those who perceived poor reading skills to be the primary functional problem in these children. Dyslexia was defined as the inability to read or obtain information from printed symbols in a way commensurate with an individual's intelligence level (Helvesten 1978).

As confusion from the conflicting terminologies, assumptions, and intervention alternatives grew, many professional disciplines focused on the complex and challenging issues.

A national project, launched in October 1964, was sponsored by the National Institute of Health, the U.S. Public Health Service, the National Society for Crippled Children and Adults (Easter Seal), and the U.S. Office of Education and carried out by task forces composed of physicians, scientists, and educators. Task Force I was instructed to work on terminology and identification factors; Task Force II was to discover existing services for children and parents; and Task Force III was assigned to delineate needed areas of basic and applied research.

The definition of minimal brain dysfunction that ultimately arose from the project's work was "a term referring to children of near average, average, or above average intelligence with certain learning or behavioral disabilities ranging from mild to severe, associated with deviations of central nervous system function. The deviations may be manifested by various combinations of impairment in perception, conceptualization, language, memory, and control of attention, impulse, or motor function. These aberrations may arise from genetic variations, biochemical irregularities, perinatal brain insults, or other illnesses or injuries sustained during the critical years for development and maturation of the central nervous system" (Clements 1966).

"Learning disabilities," first defined by the Council of Exceptional Children and later included in P.L. 94-142, became a useful term because it concentrated on the behavioral manifestations of specific deficits in learning processes, without assumptions of etiology. "A child with learning disabilities is one with adequate mental ability, sensory processes, and emotional stability who has specific deficits in perceptual, integrative, or expressive processes which severely impair learning efficiency." The sensory processes of course included vision (Hainesworth and Siqueland 1969; Ballard 1977).

Practical Programs

Programs for children with learning disabilities were developed by and for a variety of professionals searching for practical methods to restructure disorganized behavior in classroom and home settings. Some of the most popular and effective approaches used by educators, therapists, psychologists, and optometrists focused on the interaction of vision with gross-motor function as a foundation for achievement of academic skills such as writing (Kephart 1960; Getman 1962; Frostig and Horne 1964; Barsch 1968; Ebersole, Kephart, and Ebersole 1968).

Behavioral optometry, which includes developmental and functional optometry, specializes in specific vision training, one of several clinical approaches for disorders of eye movements, focusing, and visual perception as well as strabismus and amblyopia (Cohen 1988). These approaches also include the use of patching regimes, prism lenses, fusion therapy, and scotopic sensitivity therapy (tinted lenses).

According to the American Optometric Association, vision problems do not "cause" learning disabilities. However, since vision provides a solid foundation for learning, poor visual skills can interfere with remedial efforts. Vision training is a sequence of activities, prescribed by an optometrist, in which the child builds visual skills and the ability to efficiently take in, understand, and use visual information. The effects of moderate visual problems on reading efficiency was studied by the Ludlams, who introduced

a subtle mismatch with the use of prisms into the accommodative-convergence systems of normal college students. Significant differences in reading performance and comprehension were found between the experimental group (prisms) and the control group (no prisms) (Ludlam and Ludlam 1988). Because reading problems usually have multiple causes, treatment must be multidisciplinary, with educators, psychologists, optometrists, and other professionals working together. The optometrist's role is to help the child overcome the vision problems interfering with reading (Optometric Extension Program 1985; American Optometric Association 1986).

The American Academy of Ophthalmology reacted strongly to some claims that specific learning disability (SLD) was caused by poor vision, abnormal focusing, jerky eye movements, poor alignment, and inadequate eye-hand coordination. The Academy defined SLD as an educational term referring to difficulty in understanding and using spoken or written language, best helped by remedial educational programs. The Academy's position has been that a thorough medical eye examination can determine the presence of any visual defect affecting reading, but no credible evidence exists to show that visual training, muscle exercises, perceptual, or hand-eye coordination exercises significantly affect a child's specific learning disability (American Academy of Ophthalmology 1988). While insisting that jerky pursuits were a result, not a cause, of poor reading, however, some pediatric ophthalmologists often prescribed ocular motility training, usually through orthoptists in their employ (Helvesten 1978).

Despite the controversy between the fields of optometry and ophthalmology regarding the efficacy of visual training, Kephart's programs, which were designed to help school personnel, were embraced as models for other professionals who worked in collaboration with or expanded their own programs to be used by therapists, optometrists, and parents as well as teachers.

Table 2-3 describes Kephart's analysis of gross-motor skills, eye-hand coordination, and temporal-spatial translation for form perception required to accomplish the task of drawing a square.

TABLE 2-3
Drawing a Square: Task Analysis

Gross-Motor Skills

1. sitting balance with head control
2. integration of involuntary reflexive behaviors
3. differentiated, controlled, and precise movements of arm, elbow, wrist, hand, and fingers (dexterity)

Eye-Hand Coordination

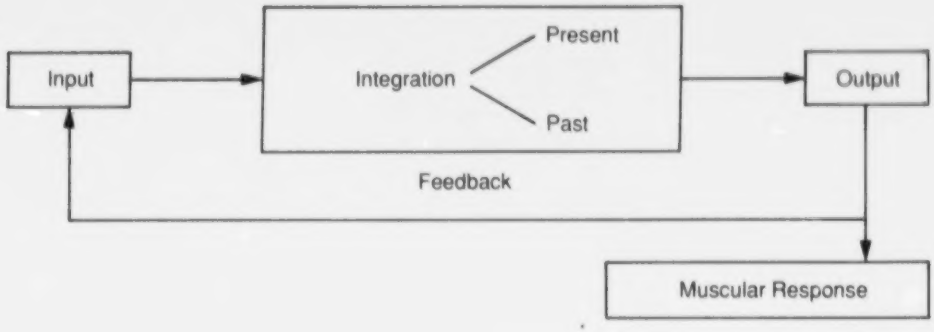
1. *laterality:* differentiation of left and right sides of the body with ability to control the sides simultaneously and separately, enabling skillful use of one hand
2. *directionality:* awareness of self in relation to objects in space and of how those objects relate to each other in order to determine which direction to draw
3. ability to start and stop movement, not only at the beginning and end of the task, but also during changes of direction (corners of the square)
4. *eye movements:* visual rather than tactile identification of directionality in distant stimuli; translation of a series of eye movements into a series of hand movements during copying

Temporal-Spatial Translation for Form Perception

production of one part of the figure at a time (separate lines and angles) while maintaining the relationship of the parts to the whole (simultaneous organization in space and serial organization in time)

Source: Kephart 1960

The perceptual process described by Kephart is illustrated in figure 2-11. He considered this process a closed system, with the input generated inside the organism by its own neural impulses activated by external stimuli. The next step in the process, integration, is concerned with the organization of multiple, simultaneous sensory inputs (visual, auditory, kinesthetic, proprioceptive, etc.) into a single, efficient motor response. Integration also includes the effects of past experience, which alters and modifies the input pattern. This elaborate pattern is then translated into an output pattern through associative mechanisms. Output, a pattern in the motor cortex, is sent to muscle groups, resulting in movement and the first consciousness in the perceptual process. Part of the output pattern feeds back into the system to become input. This feedback creates a closed system with its own control, allowing constant monitoring and continuous alteration of output until feedback matches input exactly. Thus input and output cannot be considered separately and are one perceptual-motor process.



Source: Kephart 1960

Fig. 2-11
Feedback Mechanisms in Perception

A breakdown of the perceptual-motor match may occur when incoming information conflicts with rather than reinforces other input. For example, if a child's eyes do not always work together, the child may be able to achieve fusion on objects at arm's length but not any closer. In that case, a double image would interfere with near-point tasks such as reading or writing. If the distance at which the breakdown occurred was not always the same, but depended on the child's physical state, the unpredictable visual images would contribute to inconsistent school performance. Had the child's eyes been uncoordinated all the time, the child could have learned to suppress vision in one eye. Because the unpredictability of minor and/or transient defects makes it hard for the child to learn effective ways to compensate for them, these defects may be a more serious problem for the child than a major defect (Kephart 1960).

The Purdue-Perceptual Motor Survey is an instrument that assesses the quality of school-age children's abilities and identifies and directs specific remediation in areas such as balance and posture, body image and differentiation, perceptual-motor match and form perception (chalkboard activities), and ocular control (Roach and Kephart 1966). Detailed training instructions are designed to facilitate the total perceptual-motor process of input, integration, output, and feedback. Consistency of visual as well as motor input, a crucial factor in the dynamic learning process, is assured by careful structuring of each activity (Kephart 1960).

Melinda

The influence of eye-hand coordination deficits on the development of cognitive skills (including visual perception) was emphasized in Melinda's re-evaluation at three and a half years of age. New additions to her occupational therapy program, which was still implemented in the home but with supervised student therapists supplementing the parent intervention, included chalkboard activities and visual training. "Car-on-the-road" games were adapted from Frostig worksheets, beginning with thick straight paths, gradually changing to thinner and curved lines, and finally precise tracing, leading to construction of shapes (Frostig and Horne 1964). Melinda was encouraged to use both hands, unilaterally (separately) and bilaterally (together). The therapist's decreasing manual control was provided to ensure consistent normalized input. Dot-to-dot games, double circles, directional lines, figure-eights (racetrack), and the "clock game" were used to improve Melinda's eye-hand coordination. Visual training included having Melinda follow with her index finger horizontal, vertical, diagonal, and circular patterns made with a penlight on the wall in a darkened room (Kephart 1960; Getman 1962).

Melinda's occupational therapy, speech therapy, and swimming program continued as she attended a local nursery school with normal peers age four and five and had eye surgery to weaken the medial recti muscles as well as tenotomies of both inferior obliques (Colliton 1976). At age six, when Melinda was mainstreamed into regular kindergarten, P.L. 94-142 required the public schools to provide occupational therapy and other related services to all handicapped children.

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Chapter Three
The Developmental Model: Nathan

The human eye is virtually a vestibule to the brain, and . . .
stereoscopic vision with its cortical elaborations is the crown jewel of organic evolution.
(Gesell, Ilg, and Bullis 1949, 3)

Conventional approaches to the assessment and treatment of visual problems have emphasized either the medical model of pathology concerned with visual acuity (distinguishing detail) or the educational model of cognitive processing concerned with visual perception (extracting information from visual stimulation). Very little information is found in the literature concerning the motor components of the visual action system, particularly the process of eye-hand linkage, which influences the development of both eye and hand function (Erhardt 1987). An exception was Gesell's research at the Yale Clinic of Child Development and the research of several others (Gesell, Ilg, and Bullis 1949; Ling 1942; Knobloch and Pasamanick 1974). Gesell's involvement with optometrists such as Skeffington and Getman led to new models of functional, behavioral, and developmental visual therapy (Wold 1978).

Therapists working with children who have cerebral palsy have found developmental approaches to evaluation and treatment to be useful, especially for those children with delayed and/or abnormal prehension patterns (Erhardt 1982). All children, with or without disabilities, develop within the framework of predictable progressive stages. Early reflexes and primitive movement patterns provide the foundation for more voluntary refined movements, and each step is dependent on the integration of the preceding steps (Erhardt, Beatty, and Hertsgaard 1981).

The organismic conception of development perceives the new behaviors appearing within each higher stage as qualitatively different from those at the previous stage because they represent an integration, not an addition, and cannot be reduced to lower levels of organization (Garwood 1979).

Developmental stages, however, blend together imperceptibly. For example, a child who appears to have outgrown a certain level often reverts to it for a short time before continuing development at the subsequent level. Plateauing for varying periods of time is also common, as new skills become integrated with previous ones. Individual differences are demonstrated by the variable age levels at which different children achieve particular skills or the occasional skipping of a developmental stage. For example, in a study of infants from birth to six months, Ling (1942) reported that some subjects very quickly became skilled in sustained visual fixation on a stimulus disk and remained so. Others acquired the skill with equal rapidity but their performance soon fell as they appeared to become bored with the stimulus. Still other subjects required a longer time to become proficient; some of these retained the skill, but others outgrew the activity as gaze shifts became more efficient and interesting than mere fixation.

Visual activity in infants may be similar to that in adults who encounter new surroundings. The unfamiliar environment is first systematically searched

(localization), then examined and identified (fixation). The eyes soon move on to find new and more interesting items (gaze shifts) or follow a moving target that appears within their visual field (ocular pursuit). If an infant appears to fixate for only brief periods of time on a particular object, it may be because visual acuity is limited, development of visual attention is delayed, or the object is so familiar that he or she needs only a brief glance to identify it. Also, an infant who is visually absorbed in an object may be at the stage of intensive visual exploration, or if not, the stage may be persisting longer than it should (Holt 1977).

According to Barraga, the visual functioning of a child is primarily developmental. When the eyes are operating normally, the child learns a great deal independently. However, when vision is impaired either through an optic or a neural problem, the child must be led carefully through the steps of visual development and taught to use what vision is available. In other words, visual ability is not innate and automatic, cannot be estimated by visual acuity measurements alone, is not necessarily related to the kind or degree of loss, and can be brought to potential through a sequential program of visual experiences (Barraga 1967, 1970).

Educational programs for children whose multiple handicaps include significant cortical visual problems have become increasingly sensitive to the implications of posture and movement on visual function and vice versa (Brown, Schuerman, and Crowner 1976; Corn 1985; DuBose 1976; Efron and DuBoff 1975; Fraiberg 1971; Gates 1985; Jan et al. 1987; Jose, Smith, and Shane 1980). Since developmental progress of normal children is achieved through the complex interaction of separate pathways of development (gross-motor skills, hearing and language, social skills and behavior, and vision and eye-hand coordination), neurological disorders in any of these areas may affect the pattern and rate of development, not only in the areas of occurrence, but also in each of the other areas.

Manipulation and exploration, closely linked with gross-motor activity and development of body image, are essential experiences of the sensorimotor stage in the development of human intelligence. The child's growth and development, particularly his or her body image, depend on the synthesis of vision, hearing, touch, and proprioception, of which vision is a major part (Egan 1979).

Fieber and Robinson (1974) described a group of infants with cerebral palsy and motor delays whose oculomotor problems appeared to be related to their tonic reflexes and vestibular system deficits and who used some of the primitive reflexes as compensations for their lack of voluntary control. Intervention programs for these infants were set up to use postural adaptations to facilitate oculomotor coordination and to utilize preferred stimuli. Preliminary data indicated improved functional vision in *some* of the children, including more immediate responses to combined sound-visual stimuli than to visual alone, improved ocular pursuit and shift of gaze, decreased nystagmus, more reliable blink reflexes, more visually directed reach, and increased range of motion of eyes and visual monitoring of hands.

The term *development* has been defined in its broadest sense as the result of interaction between evolution, maturation, and learning. If the definition of evolution is the development of inherited behaviors and that of maturation the unfolding of genetically determined patterns, then learning is a self-determined process occurring through the interaction of genetic and environmental variables (Gesell and Amatruda 1947; Connolly 1970; de Quiros and Schrager 1978, 1979). An important feature of development is the clear tendency toward increased organizational complexity and differentiation. As a component of development becomes functional, its further development is modified by its own activity. A common characteristic of humans and also of many animals is the ability to modify behavior as a result of previous experience. This can vary from the relatively simple forms of habituation in animals such as sea anemones to learning through symbolic systems (reading) in man. This universal plasticity of behavior implies that changes in neural structure and function must occur as a result of experience and thus continue throughout life.

Living organisms, if they are to survive, must interact with the environment in a way that maintains a dynamic equilibrium and incorporates variability and purpose (Connolly 1974). At early stages they possess methods of finding and obtaining food and ways of receiving warnings to avoid accidents and predators. Human acquisition of these biological skills can be traced to the evolution of sensory functions. Speculation about which came first—sensation or movement—is irrelevant, since they are now unable to be dissociated in terms of function.

Nathan

Nathan's delayed motor development had profound effects on his interaction with the environment. He had very little head control, rolled over with great effort in one direction only, could just briefly side sit with his arms supporting him after being placed, and did not crawl, stand, or walk. His lack of mobility prevented him from initiating the variety of activities that most children enjoy independently. His family, however, consistently provided him with opportunities to experience a wide array of the sensations as well as the movements of common childhood activities.

One such experience was a ride on a merry-go-round. The vertical motion and forward progression of the horse and the music provided Nathan with vestibular and auditory stimulation. His mother encouraged midline orientation by giving Nathan head and trunk support and helping him hold the pole with both hands (fig. 3-1). Nathan sought stability by locking his elbows in extension, a typical compensation for lack of midrange control in children with low muscle tone.

Figure 3-2 shows Nathan enjoying more vestibular stimulation through the gentle movement of the waves of the lake as he lay on an inflatable raft. At the lake, he also experienced the sensations of different temperatures and textures as he sat supported in his car seat at the edge of the water with his feet in the sand and water and the sun warming his arms and legs.

Fig. 3-1

Fig. 3-2

Roughhousing with his father and brother provided the type of proprioceptive input that children normally receive (fig. 3-3).

Tactile stimulation (as well as olfactory) was derived from exploring the texture of lamb's wool during an outing at the zoo with his father and grandparents (fig. 3-4).

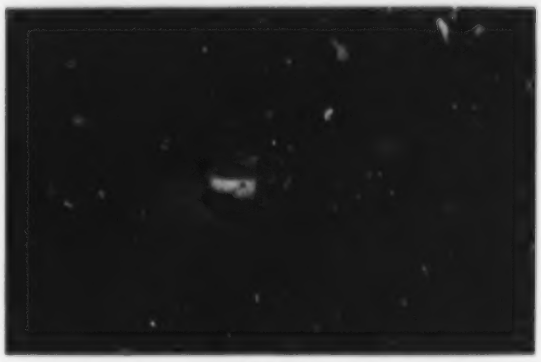

Fig. 3-3

As Nathan's little brother became mobile in an infant walker, Nathan moved beside him in an adapted, battery-operated toy motorcycle, guided by a family member (fig. 3-5).

Fig. 3-4

Fig. 3-5

Phylogeny and Ontogeny of Vision

The neurological behavior of different developmental stages depends on the maturation process of the brain, which reflects the course of phylogenesis (development of an animal species) and ontogenesis (development of an individual organism). In other words, the embryos of the fish, bird, reptile, and lower primate are similar to that of the human, starting as one-celled beings and possessing, as vertebrates, the same primitive features. But different uses are made of those features.

The fish eye adapted to the aquatic medium. Without a neck, the fish turns its whole body to watch for food or danger with eyes that are constantly aware and alert. It uses a full set of oculomotor muscles to

maintain a constant visual field—a prerequisite for detecting movement—in a very narrow binocular field, since the eyes are on the side. The chicken's ocular-prehensory powers are almost perfect when the chick hatches. The chick must, from birth, be able to pick up food using its bill with some degree of accuracy. The forepaws of the reptile, evolved from the fish's fins, show a skeleton similar to the human hand, and in the land turtle, this "hand" is connected to the brain cortex in one of the first associations with vision.

The cerebral hemispheres have no influence on fishes; the beginning of a cerebral visual center occurs in birds and reptiles. Animal studies have shown that certain types of visual function such as light sensitivity are retained in the subcortical areas, but object vision is mediated in the visual cortex in the higher mammals (Gesell, Ilg, and Bullis 1949; Peiper 1963; Nilsson 1966, 1977; McGraw 1969; Holt 1977).

In primitive animal forms, neuromuscular activities were expressed in simple and immediate reflexes so that afferent sensory impulses were transformed into ready responses. With the vertebrates the sense of smell began to govern behavior and the cerebrum became largely an olfactory center. The replacement of smell by vision as a dominant sense was a significant factor in the evolution of humanity (Harrington 1981).

The terrestrial existence of the early mammals made smell, touch, and hearing more important than vision. The snout was an organ of prehension, for digging, grasping, and handling food within the earth, thus the olfactory area of the brain was more highly developed than the areas controlling the other senses. The shift from terrestrial to arboreal life was accompanied by changes in structure to accommodate changes in function. In escaping from enemies on the ground, the animal's tactile and prehensile skills were transferred to the limbs, which developed sensitive digital pads as well as claws. Vision became increasingly important as the forest environment demanded information about size, color, texture, movement, pattern, and distance, not only concerning the acquisition of food and the avoidance of predators, but also in determining the position and distance of branches during arboreal locomotion. The increased quantity of visual information necessitated expansion not only of the visual cortex of the brain but also of the visual association areas, which integrate the visual system with total brain function (Campbell 1966; Kelso 1970).

In the course of evolution, the eyes have moved from the lateral placement on the fish and reptile to a more frontal position, allowing stereoscopic vision (an overlap in the fields of view of the two eyes). The width of the binocular field in mammals (horses, dogs, cats, monkeys, apes, man) gradually increases from approximately 60 degrees in horses (with a total visual field of 360 degrees because of the lateral placement) to 120 degrees of binocular and 180 degrees total field in man. In many lower and all higher primates, the eyes are no longer receiving input from only one half of the environment, but from both halves simultaneously. Stereopsis (the binocular appreciation of depth) is achieved on the basis of the slight differences (disparity) in this double image, as the brain is able to assess the distance of different objects (Campbell 1966).

Visual Perception in Species and Individuals

Two modes of perception have been described in similar ways by Gibson (1970) and Trevarthen (1968). Gibson considers perception of space and events in space (localizing oneself in the spatial layout and monitoring events going on in surrounding space) to be neurologically more primitive than perception of permanent objects (identifying detailed size and shape of objects).

Trevarthen discusses two mechanisms of vision: ambient and focal. Ambient vision is concerned with orientation of the head, postural adjustments, and locomotion in relation to spatial configurations of contours, surfaces, events, and objects. Focal vision is applied to one space; it is used to examine and identify a specific object.

In primates, ambient vision resembles that of primitive vertebrates in that an extensive portion of the space around the body, much more than just the frontal hemisphere, is mapped. With scanning movements of the head or whole body, an animal can obtain a quick visual impression of the large features in its immediate space. Focal vision, which obtains detail, has limited scope, but an area of interest can be brought to attention and analyzed by controlled eye movements. Focal vision appears to be primarily a function of the cortex, as experiments

with hamsters showed that when the visual cortex was damaged, the animal could localize an object in space but could not identify what it was seeing.

Ambulatory children with cortical visual impairment are more likely to be able to avoid obstacles than to use their vision for close work, probably because of their intact collicular visual system, which enables them to perceive motion (subconscious orientation during ambulation) but not to make conscious visual analyses, the function of the primary visual pathway (Jan et al. 1987).

The conclusions of both Trevarthen and Gibson were that the awareness of events in space is primitive, both phylogenetically and ontogenetically, and that development progresses toward differentiation of form and identification of objects and patterns, with learning playing a prominent role. Nature seems to have first insured the means of detecting information needed for survival—avoidance of obstacles during locomotion and awareness of moving objects (food or predators). Fine-grain differentiation of complex sets of objects is much higher in evolution and involves a process of adaptation. Eventually, in higher primates and humans, both ambient and focal visual processing are available at the same time, with one predominating during different situations and for different purposes (Trevarthen 1968; Gibson 1970).

Since the ambient, or primitive, mode of visual processing depends upon orientation of the head, body postural adjustments, and locomotion in relation to space, vision evolves from the growing movement system. All visual acts have a motor basis. All movement must be preceded by a postural set. The functions of postural reactions are to adjust to the constant pull of gravity and to the changes of position, thus maintaining balance. The eyes are intricately involved in the total action system, either responding to the shifts in body posture or initiating the shifts. The oculomotor muscles are derived from axial rather than appendicular somites; are phylogenetically ancient, found in the lowest vertebrates; and organized early in the embryology of the human infant (Gesell, Ilg, and Bullis 1949).

Vision and Posture

The functions of vision and posture begin an inseparable relationship as the infant first lifts his or her head and receives a confused visual impression of his or her surroundings. The optical righting reaction reinforces the head righting reaction, accustoming the head to a vertical position. The vestibular system begins to act on this orientation as improvement of coordination facilitates head righting in a variety of positions. The body then needs to orient itself in relation to the different head postures, which seek a vertical orientation in space as gravitational support changes. These constantly changing head positions provide the sensory system with an incredible variety of visual experiences integrated with tactile, auditory, and proprioceptive stimuli.

The neck, which contains a large quantity of sensory receptors, provides head stability for fine movements of the eye that permit focus despite body movements. The ambient visual system continues to orient the body in space while the focal visual system develops skills necessary to organize complex forms representing abstractions that will be used for reading.

Optimal eye movements are dependent on neck stability, organization of trunk responses, and free head movement that adapts to shifts in the center of gravity as the body moves through space (Langley, Nelson, and Padula 1986).

Involuntary Visual Patterns (Reflexive)

Primitive reflexes orient the organism in space, return it to the normal orientation, and assist it in directional movement. Righting reflexes are activated by stimulation to the otoliths (reacting to change of position), to the semicircular canals (reacting to acceleration of movement), and the cerebral cortex (reacting to optical change) (Gesell, Ilg, and Bullis 1949).

The Moro reflex (startle) to a backward dropping of the head consists of a wide abduction of the arms, extension of the elbows and wrists, and extension/abduction of thumbs and fingers, a postural reaction that has been described as the infant's response to the lack of expected support provided prenatally by the uterine wall. The Moro diminishes and becomes integrated at about the same time that the infant perfects head and ocular control, can sit momentarily without support, and develops protective extension of the arms (Bobath 1966).

The most rudimentary attitudinal reflexes are mediated by proprioceptive impulses and labyrinthine mechanisms, with head and neck positions rather than visual stimuli influencing trunk and limb postures. If the head is turned, the arm that the face is turned toward extends and the arm that the face is turned away from flexes. This asymmetrical tonic neck reflex (ATNR) has been observed in the 20-week fetus but reaches its maximum influence in the one- to two-month postnatal infant, promoting focal processing by channeling visual fixation on the hand in response to random arm movements. This leads to hand inspection and approach and manipulation of an object, and eventually to skilled eye-hand coordination. The ATNR is not a predominant functional pattern in older children and adults except in times of stress or for certain skilled or strenuous activities such as fencing, using a bow and arrow, digging with a shovel, and throwing a ball.

Coincidentally, the line of sight that can be measured from the pupil of the infant to the outstretched hand in the ATNR position is 10 inches to 14 inches (25 cm to 35 cm), approximately the same distance defined as the most comfortable for reading (Harmon 1958).

Beginning integration of the ATNR between three months and four months correlates with increasing midline orientation of eyes, head, and hands. Since joining of the hands at midline and visual convergence occur during the same stage in early infant development, it may not be possible to designate which is a precursor of the other.

Eye movements are also mediated at first by more reflexive areas of the central nervous system, gradually coming under more voluntary control as the components of the entire visuo-motor system undergo constant organization, adapting to environmental demands as well as structural changes in the organism (Gesell, Ilg, and Bullis 1949). Taft and Cohen (1967) found that reflex testing in infants has important clinical applications, including the following:

1. assessment of maturation and development
2. localization of central nervous system lesions
3. determination of integrity of peripheral nerves

Visual reflexes can be described as primarily involuntary visual patterns, as compared with the more voluntary eye movements of localization, fixation, ocular pursuit, and gaze shift. Certain reflexes that impact significantly on the developing child and can be evaluated by nonintrusive measures include pupillary reactions, doll's eye responses, and a varied group of eyelid reflexes.

Pupillary reactions. Bright light directed into either eye produces pupillary constriction ipsilaterally (direct light reflex) and contralaterally (consensual light reflex). The reflexes depend on the integrity of retinal light perception and the optic nerve, although they are present before the actual myelinization of the optic nerve. They are not controlled by the cortex since the reflex center is in the area of transition between the thalamus and the colliculus.

Both direct and consensual reflexes develop at the same time. Pupillary reactions are always present in normal newborns and premature infants at seven months to eight months gestational age, although the constriction occurs more slowly in younger infants and when the light stimulus is not as bright. Because the young infant cannot adapt the pupils quickly to limit the amount of light entering the eyes, the infant may turn the head away or close the eyelids, as the child does when room illumination is too bright. Disagreement among authors about dilation abilities reflect difficulties in studying preterm and term infants under varying lighting conditions, since they keep their eyes closed even under mild illumination (van Hof-van Duin and Mohn 1984). Some normal infants as well as handicapped children with unequal pupil reactions show photophobia, or marked sensitivity to light (Peiper 1963; Taft and Cohen 1967).

Doll's eye responses. When the head is turned in any direction (rotated right or left, flexed, and extended), the eyes appear to move in the opposite direction but are actually demonstrating a delayed response to moving with the head. Always present during the first ten days, the doll's eye response gradually decreases until it is integrated by three months (Illingworth 1971). These reflexive movements may serve to provide the infant with sensorimotor experiences of eyes moving separately from the head (achieved voluntarily by six months). The doll's eye response also may act as a mechanism for elongating the oculomotor muscles just as other muscles in the body are elongated from the newborn state of physiological flexion in preparation for controlled movement (Bly 1983).

Eyelid reflexes. Eyelid movements during opening and closing of the eyes (both voluntary and involuntary) frequently are not coordinated at birth. One may be open and the other closed or both not equally open. *Light* causes a reflex closing of the lids (visuo-palpebral reflex) even in sleep, when they close more tightly to light without interrupting sleep (Peiper 1963).

Moderate *sound* tends to alert a person, with consequent widening of the palpebral fissures. Loud noise, however, initiates a blink (cochleo-palpebral reflex), essentially the only consistent auditory reflex found in newborns (McEwen and Goodner 1969).

Touch activates the visual system for unilateral as well as bilateral use of the eyes. A tap over one eyebrow (McCarthy's reflex) or on the eye itself (corneal reflex) elicits a homolateral blink; on the eyelashes (ciliary reflex), a homolateral or bilateral blink; and on the bridge of the nose (naso-palpebral reflex), a bilateral blink.

The McCarthy's and naso-palpebral reflexes are present before birth in normal infants. They diminish and are essentially replaced as the defensive blink emerges and becomes established and consistent. After frequent repetition, the unconditioned closing of the lids upon touch will be conditionally connected with the approach of an object (Peiper 1963; Taft and Cohen 1967).

Blinking in reaction to threat is a conditioned response in the Pavlovian sense, not unlike the protective extension reaction of the arms. Neither is present at birth, but both begin to emerge in response to situations requiring protection and are automatic and immediate once well established. The response to a visual threat emerges in the normal infant at one month in response to a large target in a central field, and becomes immediate and consistent to even a small target in peripheral fields by five months (Peiper 1963; Taft and Cohen 1967; van Hof-van Duin and Mohn 1984). In older children and adults, both normal and handicapped, verbal cues alone can elicit a defensive blink as an anticipatory reaction, but the response can be cognitively overridden, for example, to catch a ball.

The eye-neck reflex is seen in premature and young infants during the first ten days of life. With head supported, they respond to sudden light by assuming an opisthotonic posture (total body extension), which continues throughout the duration of exposure. The response is symmetrical, even if one eye only is stimulated, and is integrated by one month in full-term infants and by three months in preterms (Peiper 1963).

Eyelid reflexes are activated by a wide variety of stimuli because of the neural connections and proximity to sensory pathways of cranial nerves V (trigeminal, or touch), VIII (auditory, or sound), and II (optic, or light). Table 3-1 includes stimulation in all three sensory modes for the elicitation of a variety of neonatal and infant visual reflexes.

TABLE 3-1
Neonatal and Infant Visual Reflexes

Reflex	Stimulus	Response	Age Range
Pupillary	bright **light** in eye	ipsilateral and consensual constriction	8 months (fetal) through life
Visuo-Palpebral	bright **light** in eye	eyelid closure	6-7 months (fetal) through life
Eye-Neck	bright **light** in eye, head unsupported	opisthotonos	8-9 months (fetal) to 1-3 months
McCarthy's	light **touch** above eye-brow	homolateral blink	6-7 months (fetal) to 4 months
Naso-Palpebral	light **touch** on bridge of nose	bilateral blink	6-7 months (fetal) to 4 months
Ciliary	**touch** on eyelashes	homolateral or bilateral blink	6-7 months (fetal) through life
Corneal	**touch** on cornea	homolateral blink	6-7 months (fetal) through life
Cutaneo-Palpebral	painful **touch**	bilateral blink	6-7 months (fetal) through life
Cochleo-Palpebral	sharp **sound**	bilateral blink	6-7 months (fetal) through life
Doll's Eye	passive head turning	delay in eye movements following head	7-8 months (fetal) to 3 months
Defensive Blink	rapid approach of target	blink	1-3 months through life

Sources: Peiper 1963, Taft and Cohen 1967, Illingworth 1971

Nathan

Primitive reflexes, still an active part of Nathan's action system, influenced most of his voluntary movements. The Moro, or startle, reflex was activated by rapid changes in position in the swing when his head was unsupported, and resulted in extension of head, eyes, jaw, and trunk, with abduction and extension of arms as well (fig. 3-6). Nathan then actively modified this involuntary response by bringing his head, eyes, and arms downward and forward as he attempted to grasp the swing pole (fig. 3-7).

Fig. 3-6

Fig. 3-7

The influence of total extension patterns can be observed again with the addition of the asymmetrical tonic neck reflex (ATNR) as Nathan was given minimal postural support by his grandparents (fig. 3-8). In order to achieve eye/head stability, Nathan used the primitive ATNR posture for any task involving near fixation and/or hand use (fig. 3-9), despite being supported on his mother's lap.

Fig. 3-8

Fig. 3-9

Levels of Visual Processing

Three levels of visual processing have been described in relation to normal gross-motor function, the effects of poor vision on development, and appropriate goals for therapeutic intervention for individuals functioning at delayed developmental levels:

Global stage (birth to two months): The normal infant displays immature, disorganized postures and random eye movements related to an unstable head and incomplete control of the neck. Most visual responses are reflexive, with ambient processing more efficient than focal. Poor vision can suppress the emergence of natural drive, awareness of the self as a person, and desire to relate to people and objects in the environment. Therapeutic goals are to organize the neuromuscular system and elicit more consistent responses.

Integrative stage (three months to six months): The infant can use both eyes together and can converge visually because of head stability and midline orientation. Reflexive responses have decreased and gaze shifts are freer because of increased head rotation. Information processing has improved with the addition of memory. Visual loss affects the ability to react and interpret sensory information from multiple channels. Goals are to facilitate integration of vision and movement and to improve goal-directed behavior.

Discriminative stage (seven months and beyond): The child uses integrated movement components to enjoy a variety of movements, promoting depth

perception and the blossoming of visual perception. Effects of poor vision are mainly on the mastery and control of new tasks that require visual components. Goals are to refine the cognitive-visual system and to perfect the optimal use of vision in preparation for functional tasks involving eye-hand coordination and reading (Sonksen 1982; Langley, Nelson, and Padula 1986).

Nathan

In figure 3-10, Nathan demonstrated global, undifferentiated postures affecting eye movement when he reached with extended arms to help his mother dig out the pumpkin. The total extension pattern of head, eyes, and jaw is overcome only with concerted voluntary effort (fig. 3-11). He has not yet reached

Fig. 3-10

Fig. 3-11

the integrative stage, where both eyes are used together and can converge. He is able to redirect his vision from the ambient mode to the focal one, but only one eye (the left) fixates on the bottle as he helps feed his baby brother (fig. 3-12). The other eye drifts outward. Visual discrimination, necessary for functional tasks, will be extremely difficult.

Fig. 3-12

Depth perception does not rely entirely on binocular vision, and many adults function adequately with the use of only one eye, since they rely on other cues for judging distance such as size, perspective, color intensity, and memory. However, Nathan's monocular vision significantly reduces his visual field and requires compensatory postural head adjustments, compromising symmetry in his entire body.

Visual Perception in Infants and Adults

Traditional views of perceptual development assumed newborn infants received fragmentary information through their senses and as they matured, gradually integrated and elaborated upon that information to produce the organized perceptual world of the adult. In other words, perception was considered to be an acquired capacity, wholly dependent on experience and learning; an infant's world has been described as "buzzing confusion."

Bower (1966) proposed a different theory based on operant-conditioning studies of depth, orientation discrimination, and size and shape constancy in infants. He observed that infants' perceptual systems register variables containing complex information but can process only a fraction of that information. He concluded that if processing capacity is limited, priority would be given to information that has definite survival value. Thus the shape of an object, which dictates the proper response to it, would have greater priority than its orientation. However, the orientation of a surface that is to be used for support would have greater priority than its shape. This evolutionarily oriented reasoning would also explain why infants misreach, despite their ability to perceive depth by three or four months, when binocular fixation and fusion begin. Changing arm length during development would preclude a perceptual-motor system geared at birth for a particular arm length, thus initial misreaching is inevitable until the infant matches his present arm length to the visually perceived distance to the object.

In summary, Bower said infants register most of the visual information that adults register, but process much less of it. Through maturation they develop increasing processing abilities.

The difficulties inherent in processing sensory information from multiple channels was vividly illustrated in an anecdote by Connolly (1970) about his 4-year-old daughter carrying a tray of glasses and coffee cups. When he asked her where she was going, he received a terse reply, "Don't talk to me," as she continued walking slowly and carefully to place the tray down. Because the motor

requirements of the task demanded her full cortical attention, she had reached her limit of perceptual-motor processing. After the tray was safely released, she was able to engage in conversation easily and explain that she was "helping Mummy." He was impressed by her ability to recognize the need to reduce her information input and processing load and her effective method of doing so.

Nathan

Since Nathan's central nervous system was still functioning at the global rather than the integrative stage, it processed information at a very slow rate, especially when multiple channels (visual, auditory, tactile, etc.) were being stimulated at the same time. This long latency period often caused problems in his interactions with others, who found it difficult to wait patiently for his vocal or motor responses. Typically, their verbal cues would be repeated several times to encourage him, but instead of responding sooner, Nathan would delay even more as each new stimulus entering his system added more information, interrupting the process of sensory input, associative processing, and motor output. The task requirements increased if the motor output required multiple-channel responses. For example, if Nathan was requested to vocalize as well as point with his hand at the same time he was trying to maintain head and trunk control in an antigravity posture such as sitting (as well as trying to direct his eyes to either move or to hold still), his response time could be expected to be even more delayed.

The motor requirements for basic antigravity positions such as side sitting and straddling a bolster are extremely demanding for Nathan. Yet active participation in dynamic postures is crucial for the integration of vision into his total action system. For such postures, Nathan utilizes the typical ATNR pattern—the jaw extends and the hands are fisted for distal stability. Nathan is able to bring his eyes downward during brief independent side sitting (fig. 3-13). Special therapeutic handling techniques by his therapist, the author, facilitate a more symmetrical head position and jaw closure during independent straddling of a bolster with feet stabilized, although the arms are still influenced by the ATNR (fig. 3-14). Eye movements begin to reflect the symmetry and dissociation of gross-motor patterns throughout the body.

Fig. 3-13

Fig. 3-14

Visual-Motor Integration

Classical theories of vision emphasized its sensory aspects, but newer theories recognize that all visual functions have motor origins. Gesell, Ilg, and Bullis (1949, 54) described the action system as an "exquisitely balanced machine," with fundamental postural patterns combined with increasingly refined eye-hand coordination. Visual reflexes such as pupillary reactions, doll's eye responses, and eyelid blink reflexes provide the automatic sensorimotor foundation for voluntary movements of localization, fixation, pursuit, and gaze shifts.

Three dynamic postural reflexes described by Gesell, Ilg, and Bullis serve to maintain a visual panorama:

1. The compensatory reflex keeps the eyes fixed in relation to a gravitational point
2. The oriental reflex keeps the eyes fixed upon a motionless object
3. The vergence reflex keeps the eyes fixed on an object in motion

The complexity of the visual-motor system can also be examined in a functional way by charting changes correlated with the following three primary neuroembryologic divisions:

> ***Skeletal (seeking and holding an image):*** These basic and primitive components of vision have embryonic origin in areas that oriented the vertebrate to its gravitational fields. Ancient reflexes present even in fishes accomplish gross postural adjustments of head and body and finer adjustments of the eyes

through the gravitational, oriental, and vergence reflexes. Still present in primates, they operate with visceral and cortical controls.

Visceral (discriminating and defining an image): These functions also are phylogenetically old and can be traced back to roles of the organism in the food-or-foe dichotomy (to eat or be eaten). The parasympathetic nervous system and the central nervous system influence the focusing mechanism, interacting simultaneously or in sequence. The evolution of vision has always been associated with instinctive movements toward and away from stationary or moving objects in space, movements that are evidence of visual awareness and localization.

Cortical (unifying and interpreting an image): Cortical influence on the evolution of higher orders of visual consciousness became increasingly important when the fusion of projected retinal images into a single image and the demands for more diversified and exact projection were achieved. Refinement of convergence coordinated with postural sets and movements for pursuit of food, use of tools, and constructive manipulation.

Horizontal, vertical, circular, and diagonal eye movements reflect similar movements in the whole body. The head, trunk, and legs rotate horizontally, flex and extend vertically, and circumduct. The arms, hands, and fingers, are even more flexible, and more correlated with visual function (Gesell, Ilg, and Bullis 1949).

The principle of simplicity in the organization of the central nervous system relates to the visual priority of the circular shape. The "primordial circle" attracts attention because of its perfection of centric symmetry. The roundness of the pupil makes the animal's eye one of the most striking visual phenomena in nature. For example, the illusion of an eye on the wing of the fragile butterfly simulates the presence of a strong adversary, nature's attempt to protect the species. Monkeys react first with attention and then fear when shown a *pair* of circles, "staring eyes," which are, in effect, two bull's eyes. Several species of birds also show avoidance reactions to stimuli that are circular or composed of concentric circles. The bull's eye pattern is one of the strongest motivations for fixation in the young human infant. Thus this innate attention holder may be a biologically determined neuromotor pattern (Mussen, Conger, and Kagan 1969; Arnheim 1974).

The primordial circle, a phenomenon of nature, can be related to the first process of creation, the shaping of cosmic whirls and spheres (planets) from undifferentiated matter in the universe. The scribbles of children show circular shapes gradually appearing from zigzag strokes. The rotations are traces of corresponding movements of the arm, which pivots around the shoulder joint. Further subtler rotation is provided by the distal joints of elbow, wrist, and finally fingers. Young children use circular shapes in their drawings to represent almost any object: a house, car, tree, etc. When they draw human figures they begin with the circle of the head. The circle is the simplest shape to perceive visually and to reproduce physically because it is the same in all directions (Arnheim 1974).

Children's scribblings as well as prehistoric art may be derived from phosphenes, commonly called "seeing stars." Phosphenes are subjective images generated within the eye and brain rather than by light from outside and presumably reflect the neural organization of the visual pathway. They can be intentionally induced by simply applying pressure to the eyeballs with the fingers, with different areas and degrees of pressure producing different designs and colors.

Many blind children have learned to stimulate themselves visually by pressing or poking their fingers in their eyes. These inappropriate and potentially harmful self-stimulation behaviors have been difficult to extinguish because of the natural craving for sensory input in situations of deprivation.

Phosphenes have been stimulated by electrical impulses for experimental research purposes. Alcohol, drugs, and certain pathological conditions such as scarlet fever, migraine, detached retina, and brain tumors have been associated with phosphenes. They also appear spontaneously during periods of prolonged visual deprivation and have been proposed as an explanation for phantoms, ghosts, or visions seen by mystics after meditations in the dark. They are even experienced by truck drivers during long, dark nights and airline pilots in cloudless, empty skies.

Studies of 300,000 scribblings made by children ages two to four of varied ethnic origins had a distinct

phosphene character and resembled electrically produced phosphenes. The drawings progressed from basic scribbles and diagrams to combinations, aggregates, and finally pictorial figures as the children became older (Oster 1970).

The cerebral cortex functions as a synthesizer and integrative interpreter by organizing visual acts in terms of the optimal needs of the action system, culminating in adaptive behavior (Gesell, Ilg, and Bullis 1949).

Early Development of Visual/Postural Adaptation

The study of human development in the field of psychology has relied heavily on visual responses, which are among the earliest complex behavior patterns to become functional in the infant's adaptation to his or her environment. Much of the literature before the 1940s was based on casual observations that yielded highly variable and contradictory results, probably due to variations in technique and controlled conditions as well as differences in objectives and terminology.

More recent studies have recognized the need to acquire more accurate knowledge of oculomotor responses in infants, since they are the foundation upon which adult visual perception is built. Methods of measuring attentional skills in infants include (1) monitoring the heart rate when a stimulus is presented, (2) measuring the sucking response (sucking stops when an organism attends to a stimulus), and (3) recording time spent looking at a stimulus, either total time or number of discrete looks (Lewis 1981).

In joint research between the department of psychology at Princeton University and the clinic of child development at Yale, infants under six months were photographed and observed to study (1) stages of development in sustained visual fixation, (2) oculomotor responses, (3) postural responses, and (4) other related behaviors. Table 3-2 presents the stages of development and corresponding oculomotor, postural, and other responses (Ling 1942).

Other behaviors affecting fixation included oral, head, trunk, and limb movements:

1. Spontaneous movements

a. ***oral:*** sucking, chewing, or swallowing movements in response to a nonedible stimulus; sneezing, coughing, yawning, and crying

b. ***head:*** curiosity about the immediate environment motivating head extension in supine, head lifting in prone, and head rotation in all positions

c. ***trunk and limbs:*** motor exuberance, a powerful physiological drive to exercise muscles and to move for movement's sake and excitement, resulting in arm waving, leg kicking, and bouncing

TABLE 3-2
Stages of Development in Sustained Visual Fixation

Stage	Age	Visual and Postural Responses
I. Absence of fixation	fetal-natal	pupils rove incoordinately; head, limbs, trunk in constant motion; movements not influenced by stimulus
II. Dawning of fixation	natal	inhibition of motion and fussing; eye in line with stimulus for brief regard; relative immobilization of eyeball; eye opening; forehead wrinkling; chin elevation
III. Sustained near-fixation	natal-1 month	active sustained regard of near stimulus; brief sporadic glances at far stimulus; line of demarcation gradually receding
IV. Pre-perfect fixation	1-3 months	intense sustained regard, diverted by yawns, body movements, habituation to stimulus, or widening interest in immediate environment, including own fingers
V. Perfectly sustained fixation	1-4 months	intense, sustained, undiverted regard, maintained during different body movements and positions
VI. Post-perfect fixation	2-5½ months	intermittent fixation, less prolonged, interspersed with shifts of gaze to more interesting stimuli

Source: Ling 1942

2. **Adaptive movements (positive and negative)**
   a. ***oral:*** mouth open during active visual fixation (positive), closed during passive disinterest or diverted regard (negative), with variations in the shape and size of aperture and muscle tone of oral structures related to eye and head movements
   b. ***head:*** chin lifting (positive), alternating eye and head rotations, and backward head movements (negative), gradually suppressed in degree, duration, and location
   c. ***trunk and limbs:*** arching the back, raising arms, bringing legs together and feet upward (positive) or stiffening the neck and pressing the head and trunk against the surface (negative)

As shown in Table 3-3, Ling's study at Yale also correlated the stages of development in sustained visual fixation with developmental steps in eye posture preference.

TABLE 3-3
Correlation between Stages of Development in Sustained Visual Fixation and Developmental Steps of Preferences

I. Absence of fixation	
II. Dawning of fixation	
1. monocular fixation: head movements place active eye on stimulus, resting eye is closed, partly open, or wandering; fixating eye is round and open more widely, upper eyelid raised and tense; resting eye is oval, upper eyelid relaxed and drooped	
2. monocular preference: active eye fixates, subordinate eye shifts to nasal corner (preferred eye leads, other cooperates)	
III. Sustained near-fixation	
1. monocular fixation	
2. monocular preference	
3. alternation of monocular preference: fixation alternates rapidly between the two eyes through rhythmic head rotations	
IV. Pre-perfect fixation	
3. alternation of monocular preference: binocular fixation, convergence, symmetrical (when two eyes are equidistant from stimulus) or asymmetrical (when one eye is slightly nearer because of head placement (see note)	
V. Perfectly sustained fixation	
3. alternation of monocular preference	
4. binocular fixation	
VI. Post-perfect fixation	
4. binocular fixation	

Note: During asymmetrical binocular fixation, one eye converges less than the other, or in extreme cases, not at all.
Source: Ling 1942

Voluntary Eye Movements (Cognitively Directed)

Localization. Voluntary localization can be described as a visual approach. The eyes reach out and contact the visual target in much the same way as the hand approaches a tangible object. Various classifications of stimuli include light, movement, color, and sound.

Since *light* is the first activation of the visual system, newborn infants will turn toward a large area of diffuse light such as a window, and when they are turned slowly away, the infants will keep their heads and eyes directed toward the light source. Head turning to light has been demonstrated in preterms as young as eight months gestational age (Peiper 1963; van Hof van Duin and Mohn 1984).

Living organisms have learned to survive by coming to terms with their environment. They have methods of obtaining food and means of avoiding predators. The development of human sensory functions reflects these biological needs.

Newborns possess the senses of vision, hearing, touch, smell, and taste. Responses of the very young infant are survival mechanisms, but as the receptors and brain mature, more complex processes analyze and interpret sensory input, and the growing child is able to gather an increasingly wide range of information about the surrounding world (Holt 1977). The baby is subjected to many stimuli and must learn to identify and select those that are most useful for self-preservation and learning. Then the child must suppress irrelevant stimuli, a demanding task. In the early stages of sensory awareness, the infant tends to be preoccupied with one single sensory channel at a time, excluding others. When that stage passes, the child learns the simultaneous use of more than one sense for a particular task, rapid switching from one to another, and the simultaneous use of several senses for different tasks (Peiper 1963).

Movement in the visual field commands the attention of animals as well as man. Motion implies a change in the conditions of the environment, and change usually requires reaction. It may mean the approach of desirable prey or of danger, information that may be essential for survival (Arnheim 1974). Moving targets and those with internal movement are seen more easily than stationary ones in normal infants as well as children with cortical visual impairment (Jan et al. 1987).

The discrimination of *color* has been the subject of much infant research, but a review of 18 studies showed consistency between only two authors in sequences of recognition or preference. A theory that color perception begins with red and yellow and develops according to the spectrum has not been tangibly proven. A factor not considered in most experiments has been the property of brightness as well as color. When independent light rays of different lengths are used, reactions to brightness, not color, occur in the peripheral visual fields. Thus, reactions to color have varied greatly depending on whether the eye is adapting to lightness or darkness (Peiper 1963). Since color perception is represented bilaterally in the brain, in contrast to form perception, and requires fewer neurons than form perception, only extensive cerebral lesions or achromatopsia (deficiency of cones in the retina) will eliminate it (Jan et al. 1987).

At first, the infant's response to *sound* depends on the nature and intensity of the sound. Sharp, harsh noises elicit reflexive blinks. Soft, pleasant sounds result in eye widening but no head turning in the newborn. The developing awareness of sound is soon linked with the turning of the head toward the general location of the sound, a semi-reflexive action initiated by the reception of auditory stimuli that is stronger on one side than the other. This head turning can occur in babies with poor vision. When awareness is more highly developed, the infant turns both head and eyes toward the sound. At the next level, a distinct two-phase action occurs as the head turns to the side and then either downward (first) or upward. These two movements gradually merge into an arclike movement and finally into a single direct movement, localizing the sound with almost perfect accuracy.

As eye-head turning becomes consistent, it is associated with visual recognition of the sound-producing object. The maturation of auditory localization develops simultaneously with the awareness of object permanence. The ability to hear a sound and turn toward it is no longer a simple reflex action. It is associated with the concept of the particular sound as well as with the ability to inhibit the response in certain circumstances when it is too familiar, uninteresting, or the infant is engrossed visually or tactilely. Table 3-4 presents the developmental sequence of sound localization (Murphy 1962; Holt 1977).

TABLE 3-4
Localization to Sound

Age Range	Direction
natal	No turning to sound
2-3 months	Lateral turning to general direction of sound
3-4 months	Lateral turning to side of sound
5-6 months	Lateral, then downward turning to sound below ear
6-7 months	Lateral, then upward turning to sound above ear
6-7 months	Curved arc downward turning to sound below ear
7-8 months	Curved arc upward turning to sound above ear
8-10 months	Direct diagonal turn to sound below or above ear

Sources: Murphy 1962; Holt 1977

Fixation. Fixation has been described as "grasping with the eyes" (Illingworth 1971, 178). It is defined as the directing and relative immobilizing of the eyes so that the target lies on the visual axis, its image falling on the fovea. The term *relatively immobile* is used because the eyes are never immobile. Displacement of the retinal image occurs continually because of head movements, pulsation of blood vessels, and constant changes in the state of the lens and size of the pupil. Additionally, if the adult pupil is observed through a magnifying glass, the rim of the iris can be seen in a state of constant restlessness. Continuous minimal fibrillations occur between 30 and 120 times per minute. These cannot be suppressed voluntarily. They are not present in newborns, but appear gradually at four months to five months when the infant becomes excited and are correlated with higher brain functions and affected by external stimuli, emotions, and mental effort. The purpose is to protect the fovea from overexposure. Exhaustion is then avoided, and the eye can perceive a target continuously (Ling 1942).

Focal fixation begins at one month, first on targets of moderate size, about one or two feet away, and clearly distinct from the background. Slight movement aids fixation, and the more interesting the pattern, the longer the duration. The parent's face possesses all the characteristics that encourage fixation. He or she responds to the infant's gaze with facial animation, eye and eyebrow movements, and vocalization, which is mutually reinforcing. By four months the infant's interest in faces extends to his or her own in a mirror, although the child will attend to a parent's mirror image as early as two months (Illingworth 1971; Holt 1977). The ability to fixate is

greatly enhanced as stability of head posture is obtained. Controlled head movement and change of body position make a wider area of the visual field available for exploration.

The infant begins fixation with monocular vision, since extraocular control of both eyes to gain fusion is not yet possible. The inactive eye either closes or its image is temporarily suppressed or ignored by the brain to avoid a doubled or superimposed image. Thus, the infant learns to control the movements of each eye separately. At first the infant prefers one eye but soon alternates between them. When control of each eye is well established, both eyes can begin to integrate, gradually developing binocular vision. The visual fields must overlap so that corresponding parts of each retina form similar images. By trial and error, the infant learns to associate the visual fields and fusion becomes established (Illingworth 1971).

In normal binocular vision, an image of the viewed target falls on the fovea in the retina of each eye, producing impulses carried along the visual pathways to the occipital cortex. The merging of two separate, slightly different images into one is called fusion. The monocular fields of each eye overlap, producing a central binocular field, and each eye has an outer visual area not seen by the other. This outer area helps to locate targets toward which the more discriminating central binocular vision may be directed (fig. 3-15).

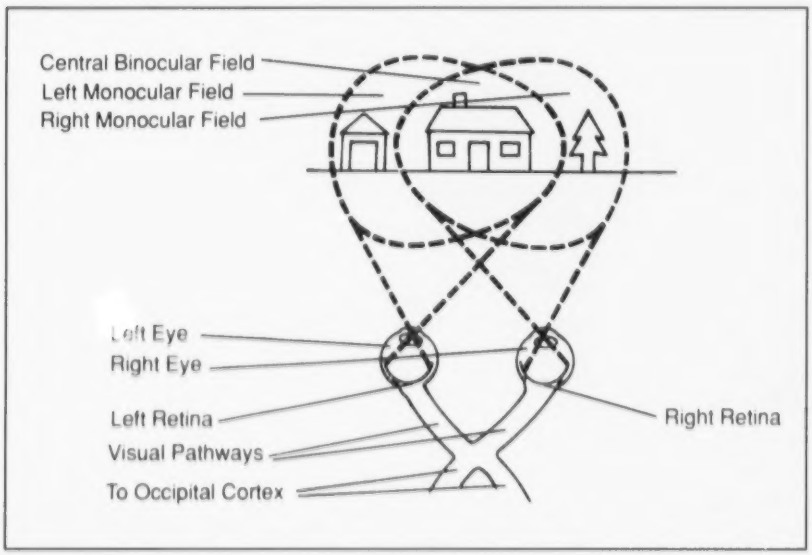

Fig. 3-15
Binocular Vision

When the eyes are placed so that the image falls on the fovea of one eye but not the other, the second eye is deviating, a condition termed strabismus. Occasional deviations of eye movements are common in the first six months, but constant strabismus during that time, and especially after, indicate a risk of irreversible monocular vision, either alternating, or one eye only, with suppression of one image to avoid diplopia (superimposition of double images).

Fusion is measured by ophthalmologists and optometrists with a major amblyoscope, an instrument that can determine the levels of binocular perception, or grades of fusion. Grade one is the ability to see with each eye at the same time, binocular vision, but not fusion. Grade two is fusion of two images so they are perceived as one. Grade three is stereopsis (perceiving depth through comparison of two slightly dissimilar images), and cannot be achieved unless grades one and two are present. The amblyoscope is also used in orthoptic therapy to improve fixation, fusion, or rotational eye defects (Kirk 1981).

Kephart (1960) believed visual training should follow the developmental sequence of the normal infant. He found some children with learning problems to possess apparently adequate fixation (stability) and/or pursuit (mobility) when tested with both eyes open, but extremely poor ocular control when each eye was tested alone. He surmised that these children had developed adaptations to the demands of their environment without the necessary prerequisites. Their apparent binocularity was achieved by "tying" the two eyes together rather than by integrating two separate control patterns. The resultant inefficiency was reflected in their increasing difficulty with demanding visual tasks such as reading.

Physically handicapped children, especially those with significant differences of each side of their bodies, have demonstrated similar compensatory functional patterns. A child with hemiplegic cerebral palsy, who uses one side of the body for stability and weight bearing and the other for mobility, will often reveal identical usage of the

homolateral eye when the eyes are tested separately. The stable eye does better with fixation tasks, while the mobile eye shows better pursuits and gaze shifts. With both eyes open, the child "piggybacks" the less efficient eye on the leading eye, or "ties the two together." True integration has not been achieved.

Pattern preference begins by eight months gestation, with infants showing marked changes in visual preferences during early months. Differences exist in the ages of appearance and the strength of preferences, but the sequence has been consistent. Young infants are strongly attracted to the contrast of black-and-white patterns, with the bull's eye a compelling stimulus, favored at two months over stripes, and remaining so throughout life (Fantz and Nevis 1967).

Ocular pursuit. Momentary pursuit of a slowly moving target has been observed at seven and a half months gestation (van Hof-van Duin and Mohn 1984). Beginning pursuit movements are not gliding in nature, but jerky, as if composed of many small changes of fixation (saccades). The transition to smooth pursuits occurs between three months and five months (Peiper 1963).

At birth the baby can follow a moving target with difficulty in very short ranges of about 45 degrees, from about 60 degrees from periphery to midline and back to the side, eyes together with head. The infant increases the range toward midline, but because the head's resting position is at the side, eyes and head return rather than crossing midline. As head control improves and midline orientation begins between two months and three months, the process of crossing midline begins with short distances, about 90 degrees, slightly past midline, gradually increasing, but with many pauses and refixations, particularly at midline.

Even at three months when the infant's eyes are able to track through 180 degrees horizontally, the eyes do not quite match target speed and jerk at midline until pursuit movements are perfected (Illingworth 1971). Tracking in all directions with eyes separate from the head should be perfected by six months (Holt 1977).

Midline represents a perceptual-motor discontinuity. The paired brain switches control at the midline of the body and its visual space. Early movements of the infant's arms and legs are from inside out or outside in, terminating at midline. In crossing midline, a hand must first move from the outside inward and without hesitation, continue from the inside outward on the opposite side of the body. Efferent control of the right-hand movement from right to left is in the left hemisphere, while the afferent visual input is received from the right visual hemifield in the left visual cortex. When the midline is crossed, the efferent motor control remains in the left hemisphere, but the afferent visual awareness emanates from the left visual hemifield and is received in the *right* visual cortex. The smooth shift required in moving from one hemisphere to the other is a learned skill and often absent in children with even mild central nervous system dysfunction (Arner 1978).

Convergence is defined as the process of using extraocular muscles to direct the visual axes of the two eyes to a near point (simultaneous turning of the eyes inward). Divergence is defined as the same process used to direct the axes to a point further away (simultaneous turning of the eyes outward). Until both eyes begin to work together at two months, only one eye will follow a target upon its approach or retreat. Beginning vergence movements are accompanied by short jerks, blinking, and overconvergence or divergence as the eyes attempt to match the process with accommodation (focusing). Accommodation and convergence are accompanied by pupil constriction in the mature eye (Peiper 1963).

Compensatory eye movements occur when constant fixation on a stationary target is maintained during head rotations. These begin in a rudimentary form during the first month, with eyes remaining on the target during head movements of very low velocity and limited scope. By one month, movements of moderate speed and excursion are efficient, and at two months, even abrupt extensive head movements do not cause diverted regard. No interval exists between the shift of eyeballs and head (movements are simultaneous), but the eyeball nearer the direction in which the head moves will shift further than the eyeball that is further away (Ling 1942). Compensatory eye movements are elicited by sensory input from proprioceptors of neck muscles, eyes, and otoliths. In lower mammals, their purpose is to avoid, as much as possible, changes of retinal images during head and body movements while pursuing prey or escaping from predators. In higher animals, compensatory eye movements are accomplished voluntarily. They are differentiated from involuntary doll's eye responses, which occur without intentional fixation (Peiper 1963).

Gaze shift. Involuntary eye movements are typical of the newborn and are characterized by conjugate deviations, symmetrical movements of the eyes in the same direction at the same time (Ling 1942). As more voluntary movements begin, the eyes move independently from each other, or one eye moves and the other does not. These rudimentary gaze shifts occur first between targets in the same focal length. They are characterized by overshooting, inaccuracy, and blinking, which is differentiated from periodic blinking (infrequent in infants) by obvious linkage with the infant's attempts to release the passive stares of ambient fixation, and later, focal fixation. As purposeful movements occur more often and more accurately, purposeless ones become increasingly infrequent, finally disappearing. Blinking decreases as shifts become more facile, but reappears when new, more demanding tasks such as shifts between targets in different focal lengths increase the infant's stress. Voluntary conjugate deviations become perfected by four months (Peiper 1963).

The significance of blinking during the gaze shifts required during reading was noted by Walsh (1974), who included it with refixation, binocular difficulties, refocusing, and head movement as evidence of visual adjustments used by children with cerebral palsy in a study of ocular motor performance.

Summary. The motor components of vision have been described as a developmental sequence of clusters of skills that are either involuntary (reflexive) or voluntary (cognitively directed). Table 3-5 lists the developmental sequence clusters of the motor components of vision.

TABLE 3-5
Developmental Sequence Clusters of the Motor Components of Vision

Section 1. Primarily Involuntary Visual Patterns (Reflexive)
a. Pupillary reactions
b. Doll's eye responses
c. Eyelid reflexes
Section 2. Primarily Voluntary Eye Movements (Cognitively Directed)
a. Localization (visual approach)
b. Fixation (visual grasp)
c. Ocular pursuit (visual manipulation)
d. Gaze shift (visual release)

Eye-Hand Coordination

The developmental process of eye-hand coordination is complex. Infants first learn to explore an object with their eyes alone as focal vision begins and with their hands alone when they accidentally come in contact with their own bodies, clothing, or blankets.

As their eyes begin to watch their hands and see their hands interacting with objects, the exploration provides sensory information that *matches* when compared. Thus, the following sequence proceeds:

1. awareness of tactile contact
2. repetition of action, first accidentally, then purposefully
3. visual control of movements
4. visual direction of active reaching
5. correlation of tactile impressions of object with visual impressions of same object
6. ability to manually move object of interest into a visual field within a stable spatial world (Ebersole, Kephart, and Ebersole 1968).

The infant's mouth, of course, serves as the first and most important sensory organ as well as a tool. It feels, tastes, grasps, and sucks. The infant's hands, equally important for sensation and function, soon bring everything to the mouth for examination. The eyes gradually gain predominance as the infant gains the ability to recognize objects as separate from the surroundings, without needing to manipulate them with mouth or hands (Peiper 1963).

Table 3-6 correlates the stages of eye function and hand function and the interrelationship between them from birth to six months.

Nathan

Delayed motor development and inadequate regulation of muscle tone prevented Nathan from beginning the process of coordinating eyes and hands. Random and reflexive hand and eye movements did not evolve toward the smooth, purposeful interaction needed for successful function. Without normal tone and postural control, his voluntary eye and hand movements were predominated by functional use of reflexes and compensations for developmental gaps, which manifested themselves in abnormal motor patterns.

TABLE 3-6
The Development of Eye-Hand Coordination

Age	(Vision/Prehension Schemas) Eyes	Hands	Interrelationship
Natal	Random eye movements and vague regard of surroundings	Random and reflexive hand movements	No visual attention to hands
2 months	Attracted by movement in periphery; monocular or bi-ocular fixation	Arms activate in response to stimulus; fingers open and close reflexively	Regards hand in ATNR position only, with one active eye; releases gaze to surroundings
3 months	Briefly regards own moving hand spontaneously; localizes noisy, illuminated, or moving targets	Swipes and contacts object at side, not midline	Watches own hand reach and contact object; alternates glances from hand to object
	Tracks targets with difficulty through 180 degrees; converges and diverges on targets moving toward and away from self	Sustains grasp on objects placed in hand	Visually searches for object at point of disappearance but cannot combine reach and grasp
	Begins vertical tracking downward, losing target	Releases object involuntarily with awareness after sustained grasp	No retrieval of dropped or lost object
4 months	Binocular fixation	Reaches with both hands, contacts, and pulls object back against body or into mouth	Brings object to mouth without visual monitoring, then relocates after removing
	Prolonged, selective fixation on target in midline	Midline fingering	Maintains fixation on own hand or object in hand
	Visually pursues lost target outside visual field	Does not reach for lost object	Retrieval not possible when hand and object are not in same visual field
5 months	Shifts gaze (releases fixation) while grasping, manipulating, and mouthing target; jerky vertical and diagonal tracking	Reaches with both hands to corral, grasp, and maintain grasp while shaking object, shoulder motion only	No visual attention to hand shaking (manipulating) object
	Visually pursues lost target outside visual field	Hands pursue lost object	Tries to retrieve lost object outside visual field
	Fixates on tiny target (pellet)	No attempt to grasp pellet	Visually attends to pellet but doesn't approach
6 months	Localizes large and small targets	Reaches and grasps with one hand and shakes object (manipulates it)	Alternately looks at, mouths, shakes object, retaining grasp
	Fixates intensely on pellet	Contacts and rakes pellet	Fixates on pellet while reaching, contacting, and raking
	Visually pursues lost target outside visual field unless distracted by another target within visual field	Adjusts body position to reach object outside visual field	Searches for lost object with eyes, hand, and body movements
	Shifts gaze in same focal length and within different focal lengths	Alternately grasps, mouths, looks, drops, grasps, transfers, and shakes object, shoulder and elbow motion	Shifts gaze during adaptive interaction of eyes, mouth, and hands

Sources: Flavell 1963; McGraw 1969; Erhardt 1982

Localization appeared to be Nathan's most efficient type of voluntary eye movement. The primitive nature of movement and sound stimuli facilitated eye/head responses, which while not as rapid and accurate as those of a normally developing child, were significantly better than his fixation, pursuit, and gaze-shift skills.

Fixation, the only voluntary visual skill requiring the ability to stabilize rather than move, was also developmentally delayed. Like most hypotonic children, Nathan used the ambient mode of visual processing most easily. He was vaguely aware of his surroundings and would fixate, or stare into space. Focal vision, however, required tremendous effort and recruitment of primitive stabilizing postures such as the ATNR. Nathan's problems with achieving postural stability and focal vision affected his visual perception because in order to examine and identify an object in near space, the eyes must be relatively immobile. Vocalizing faces, which possess the properties of sound, internal movement, and pattern/contour, were the most compelling visual stimuli for Nathan.

Alternating esotropia (inward turning) was observed by his ophthalmologist at four months of age. A surgical muscle recession was performed on his left eye at 18 months. As Nathan grew older, both eyes became increasingly exotropic (outward turning), alternating between left and right monocular fixation. A photograph at four years of age shows the corneal reflection of light centered on the pupil of his fixating left eye and located nasally on the pupil of his deviating right eye. This demonstrates that at that moment, Nathan was using his left eye only (fig. 3-16). With each passing year, Nathan's chances of achieving binocular fixation or fusion decreased.

Fig. 3-16

Ocular pursuits were even more difficult for Nathan than localization of fixation. Deprived of the variety of normal body movement experiences and without smooth oculomotor mobility, he was not able to track moving objects effectively. Eye and head movements were jerky, following a target only in very short ranges. Without binocular vision, he had no true convergence. Attempts to follow an approaching target were characterized by either deviation of the inactive eye or indications of excessive, unsuccessful effort (involuntary convergence and increased muscle tone throughout his body).

Gaze shifts were so slow and inaccurate that they could better be described as relocalizations, rather than the simultaneous release and refixation seen in the normal six-month infant. Involuntary shifts were still in evidence, and were easily detectable when Nathan's eyes moved more conjugately than during voluntary, laborious shifts. He blinked to release ambient fixation only, since focal fixation was not well established enough to require a blink for release. Gaze shifts between targets in different focal lengths were even slower than those in the same focal length, and scanning three or more targets was a painstaking, inaccurate process, with long latency periods.

When Nathan entered school and was presented with academic material, especially that involving choices to be indicated with hand pointing, he used crude scanning movements to perceive all the images presented. He then compensated for his inadequate fixation and gaze shifts by using his excellent visual memory to point with his hand to the correct choice without concurrent visual attention.

Like many children with severe low-incidence handicapping conditions, Nathan lived in a small rural town where pediatric occupational and physical therapists were scarce. At first, his parents drove him 200 miles round trip for weekly occupational therapy. He strongly resisted handling sessions with crying and stiffening behaviors that continued when he next received physical therapy at a local hospital and occupational therapy in his home. His parents and extended family tried to carry out the evaluating therapists' recommendations for therapeutic handling and positioning, but without ongoing and consistent professional intervention, progress was slow.

He finally responded positively to a friend of the family who was hired to help expand Nathan's social interactions beyond members of his family. She worked with him two to three times a week under the supervision of the occupational therapist until Nathan entered preschool at the age of three and a half years. Special educational services included speech therapy, occupational therapy, and provision of a full-time management aide. Nathan's

first Individualized Educational Plan (IEP) emphasized eye-hand skills necessary for communication such as sustaining eye contact, making choices with hand pointing, and operating switches for toys. Nathan's social development improved rapidly as he adjusted to a variety of professional and paraprofessional team members as well as other children in the class.

At the age of five, Nathan was integrated into regular kindergarten with nonhandicapped peers for part of each school day while continuing in the preschool program. Adaptive physical education and physical therapy were added as related services. He demonstrated a high level of motivation to participate in the kindergarten academic and social activities.

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Chapter Four
The Functional Model: A Normal Young Adult

For the Lord hath made the seeing eye part and parcel of an indivisible, integrated, growing action system.
(Gesell, Ilg, and Bullis 1949, 13)

As children with developmental disabilities grow toward adulthood, program goals focus more sharply on preparation for maximal independence and integration into community life. The acquisition of adult life skills is a challenge to be met by non-handicapped young adults as well as those with handicaps. The visual components of activities in a normal adult's daily life can be analyzed to provide a structure for assessment of the functional needs in young adults with developmental visual dysfunction.

This functional model, however, must be based on the assumption that visual function has matured, that is, reached a normative level where all essential motor components are achieved. The visual structures not only must be intact (anatomically) but also must be working (physiologically).

The Maturity of Visual Function

The human eye has been compared to a camera. Although there is some truth to that analogy, it does not encompass the developmental factors that have determined the structure and organization of visual functions from infancy through childhood to adulthood. Sight is more than an organ consisting of a dioptic lens and retinal film. It involves large areas of the cerebrum, the autonomic nervous system, and the neuromuscular system in the entire body. Visual functions need to be examined in terms of the organism's behavioral reactions to specific stimuli. The importance of vision in the sensorimotor construction of the human action system is exemplified by the fact that each eye, with more than 100,000,000 photoreceptors, transmits as much information to the brain as does all the rest of the body.

Visual science has provided a vast amount of basic information on the mechanisms and efficiency of seeing derived from studies of the mature adult eye, but relatively little is known about the genesis and growth of visual functions. Assumptions have been made that the eyes of a child operate in the same manner as those of the adult. Development of vision in the human infant, although reflecting its long evolutional process through the species, is subtle and swift, compressed into the first half-year of life, thus not conspicuous or in obvious stages. While the child cannot report subjective visual experiences as the adult can, a careful observation and analysis of an infant's motor responses to visual, auditory, and tactile stimulation can yield information about underlying processes (Gesell, Ilg, and Bullis 1949).

The extent to which vision stimulates and facilitates effective psychomotor, perceptual, and cognitive development cannot be determined precisely. The question frequently asked is: Does vision promote movement or does movement promote visual search and control? Obviously, sensorimotor development proceeds more rapidly when reciprocal action between vision and movement is optimal. For

example, movement toward an object is more likely to occur when it can be seen and it is something of interest.

Vision, even without movement, provides a wide variety of vicarious experiences that become part of the developing child's knowledge of the world. Vision extends the quantity of information available and provides unique sensory data that is never quite as accurate when gathered by other senses. Specific details of form and color and spatial relationships can be perceived only through vision. In addition, as a prime unifier of all other sensory information, vision provides an intact concept of the totality of what is seen. Visual images held in the brain also become a constant referent system for recall, even after objects are no longer visible. Vision, therefore, permits the developing child who learns through imitation of actions to refine motor coordination with visual reality (Barraga 1976).

The need to understand these developmental visual processes led to an intensive literature search for data to construct a comprehensive sequential model of visual-motor behavior.

The compilation and comparison of developmental norms of vision from approximately 30 different literature sources resulted in significantly consistent sequences from the prenatal or fetal level to six months. About one quarter were from medical studies and texts, another quarter from educational journals and books, and the remaining half from the fields of child development and developmental psychology (Erhardt, Beatty, and Hertsgaard 1988). A videotaped study of visual development in normal babies during the same period supported the compiled norms in developmental ages as well as sequences (Erhardt 1986).

Since essential motor components of vision are developed and functional at approximately six months, increased perceptual skills and eye-hand coordination are gained through learned experiences and interweaving with the total cognitive and motor-action system. Thus, the six-month level can be considered a significant stage of maturity in visual-motor development and can be used as an approximate norm in assessing developmental components of vision in older children and adults (Peiper 1963; Mussen, Conger, and Kagan 1969; Hatfield 1979; Hoyt, Jastrzebski, and Marg 1983).

Primitive reflexes such as pupillary reactions, doll's eye responses, and eyelid reflexes, which are necessary physiological substrata for complex voluntary eye function, are well integrated by six months. Voluntary patterns of localization, fixation, ocular pursuit, and gaze shift have been perfected almost to the level of the normal adult. The eyes move independently from the head to extreme right and left fields, and to near, middle, far, and distant space to localize targets. Both eyes work together as binocular fixation is maintained on targets of all sizes within all focal lengths and in central and peripheral fields. Visual tracking is smooth and well contained in horizontal (through 180 degrees), vertical (through 130 degrees), diagonal, and circular directions, as well as during convergent and divergent movements. Shifting gaze between two or more targets is accomplished easily and accurately within the same focal length and between different focal lengths. Eye-hand interaction is adaptive, dynamic, and coordinated (Erhardt 1986).

Both ambient and focal visual processing have reached full development by six months and are part of a repertoire of mechanisms accessible and adaptable to changing environmental demands. The retention of ambient vision, an early evolutional and developmental stage, is reflected in the scope of the visual field, defined as that portion of space in which objects are visible to the steadily fixating eye. It has been described as somewhat more than half of a hollow sphere, with clearest vision at the central visual axis, a stationary fixation point. In order to be perceived in the peripheral fields, stimuli must be larger and brighter. In the normal eye with 20/20 vision at the fixation point, acuity decreases rapidly towards the periphery. Table 4-1 presents the reduction of visual acuity from central to peripheral fields.

TABLE 4-1
Normal Acuity within the Visual Fields

Degrees from Visual Axis	Acuity
0 (central fixation)	20/20
2	20/30
3	20/40
5	20/70
10	20/100
20	20/200
40	20/400

Source: Harrington 1981

Clinical perimetry, or measurement of the visual field, is not considered an exact science because the scope of the visual field varies in the normal population as well as in a single individual over a period of time, depending on age, health, energy level, concentration, lid aperture, and lighting conditions, especially the ratio of background light to stimulus illumination (Harrington 1981).

Visual Components of Daily Living: Assessment of the Environment

Although vision is the most adaptable of all physiologic functions, possessing the power of rapid restitution after fatigue, the visual demands of school and modern urban life have put strains on the eyes. In recent years, visual maladaptations and defects such as myopia and strabismus have increased in otherwise normal children and adults, and according to some studies are linked with higher intelligence (Schrock 1978).

Because seeing is inseparably and profoundly integrated with posture, movement, hand skills, intelligence, and personality, the entire person must be investigated in terms of his or her total environment to understand how vision is coordinated with all activities of daily living (Gesell, Ilg, and Bullis 1949). In other words, assessing a person's environment is as important as assessing his or her abilities. Analysis of the components of vision can be determined only in terms of function. Table 4-2 presents examples of the variety of objects viewed from infancy throughout adulthood.

During reading and other near-point tasks, the eyes need to focus and work together as a team, making adjustments without conscious effort and coordinating movements of the hands as they operate tools and machines. These skills are particularly important in learning and working in today's increasingly mechanized world.

The majority of children spend at least 12 years in classrooms. In the classroom, coordination of eyes and hands needs to be accomplished accurately and quickly, as when looking back and forth from a book or paper to a chalkboard or teacher. To localize books, chalkboards, or other objects in space, the child must make reliable judgments of what the object is, how big it is, and its speed and direction if it is moving. Then the child must determine the proper response and act on it.

TABLE 4-2
Typical Visual Targets in Different Focal Lengths

Distance	Age	Targets
Near (1"-12")	Infant	Mother's face or breast, bottle, mobile on crib, food on highchair tray, own hand or toy in hand
	Child	Picture book, letters, words, puzzles
	Teenager and adult	Own face in mirror (shaving or applying makeup), wrist watch, newspaper, book, typewriter or computer keyboard, telephone, restaurant menu, price tag, needle being threaded
Middle (1'-6')	Infant	Faces and figures
	Child, teenager, and adult	Television, teachers, garden flowers, pets, clock on wall, fast-food wall menus, cleaning chores
Far (6'-20')	Infant	Vocalizing family members
	Child	Squirrels in trees, ducks in ponds, zoo animals
	Teenager and adult	Street and community signs, billboards, cars, balls and other players in sports
Distant (20'-infinity)	Child	Clouds, kites, airplanes, hot-air balloons
	Teenager and adult	Stars, moon, birds in flight, sunsets

Every action involves the visual system. The college student taking notes from a book works efficiently, selecting needed information immediately from other pieces of unneeded information and transforming it from the visual mode to written symbols on paper. The gardener visually guides his shovel to dig accurately, move the filled shovel carefully, and deposit the contents appropriately. The visual skills needed for reading and digging differ. The student works at near distance and needs to visualize and manipulate symbols while maintaining static posture. The gardener works at a farther distance and needs to localize and fixate on the visual target despite vigorous postural shifts. Both possess smooth eye-hand coordination, sustained visual fixation, and the ability to shift gaze and change focus without being distracted by the mechanics of seeing and doing. With efficiency in visual performance, both are free to think and to plan succeeding actions, and both possess energy reserves available in times of stress (Wold 1978).

Educational-vocational programs for mentally, physically, and visually impaired youth have been designed to prepare them for productive lives and provide them with opportunities equal to those of their nonhandicapped peers. The following outline of a composite of typical programs identifies components of visual function in the life of a normal young adult such as a college student, who can serve as a model for the maturity of vision.

I. Personal and social skills for independent living

A. Personal care and management
1. grooming: bathing, brushing teeth, applying makeup/shaving, caring for hair, skin, and nails (requires visual fixation on body parts and mirror image)
2. eating (requires visual localization of food and utensils)
3. dressing (requires visual discrimination for selecting appropriately)
4. health: taking medications, applying first aid (requires scanning for reading instructions)

B. Social skills
1. manners and appropriate behavior (requires visual attention with eye contact)
2. knowledge of current events (requires scanning for reading newspaper, fixation for watching television news)
3. dining out (requires scanning for reading menus)
4. games and leisure activities in the home and community (requires eye-hand coordination)

C. Home management (requires scanning for reading labels, visual discrimination for inspecting for cleanliness, eye-hand coordination)
1. purchasing food for and preparing meals, washing dishes
2. purchasing and using materials for house cleaning
3. maintaining and repairing simple household items
4. managing personal finances and budgets, banking
5. selecting, purchasing, and caring for clothes: washing, ironing, mending

II. Communication and job preparation (requires scanning for reading, ocular pursuits for writing)

A. Information gathering
1. using library and other resources
2. attending classes and courses
3. filing and retrieving information and materials

B. Written and oral communication
1. writing, typing, using calculator or computer
2. using telephone, speaking

III. Independent mobility (requires visual localization and fixation in near, middle, and far space; ocular pursuit of large moving objects; gaze shifts or scanning of environment)

A. Orientation of self in environment
1. organization of time: use of watches, clocks, calendars, schedules
2. efficient movement and spatial orientation: estimates and measurements of size and distance

B. Organization of work and study areas
1. arranging materials and equipment for efficient use
2. maintaining orderly work area and returning objects to designated positions during varied situations

C. Independent travel
1. ambulating in home and neighborhood
2. using public transportation for school/work
3. traveling in unknown urban, suburban, or rural areas

(Barraga 1976; Attainment Company 1988a, 1988b, 1988c)

The College Student

The alarm clock rings sharply in the student's bedroom. Her eyes, still closed, flinch in response to the loud noise. As she begins to try to wake up, her eyes react to the morning light with pupillary constriction and partly closed lids (fig. 4-1). She gropes for the alarm button, locating it easily from past experience without visually monitoring her hand.

Fig. 4-1

Ten minutes later, the snooze alarm rings, and she reluctantly gets out of bed. Ambient visual processing functions as she moves half-awake through the small room, avoiding furniture obstacles. She stands at the closet, searching for clothes to wear on the first day of college classes, shifting gaze back and forth (in the same focal length), trying to make a decision. Finally she dresses, checking carefully to make sure her socks match her sweater as well as each other.

The morning ritual of brushing her teeth, curling her hair, and applying makeup requires more discriminative focal processing at the mirror (fig. 4-2). Head turnings during this process are accomplished without losing visual fixation, an example of compensatory eye movements. Preparing a quick breakfast also requires sustained fixation as she monitors the level of juice poured into a glass to prevent overflow. Her eyes converge as she follows the glass brought to her mouth, and her gaze releases into space as her lips touch the glass.

Fig. 4-2

Ready to leave, she uses a series of scanning eye movements to find her purse and assorted school supplies. She localizes the small keyhole, locks the door, and walks to campus several blocks away. Ambient processing provides awareness of environmental obstacles such as approaching curbs and low-hanging tree branches. As she crosses a street, her eyes and head localize immediately to the warning sound of an automobile horn. Sitting in her classes, she shifts gaze frequently from the notebook in which she writes (near space: within 1'), to the teacher talking at the front of the room (middle space: 1'-6'), and somewhat impatiently, to the clock on the wall (far space: 6'-20'). Working on a computer in the library, her eyes repeat the discrete scanning movements used in reading print material: horizontally left to right, then right to left and vertically downward to find the next line, then left to right, and so on.

With classes over for the day, she joins her intramural basketball team for its weekly game. Her eyes diverge as they follow the path of the ball after she throws it at the basket and horizontally track the player who recovers the missed shot. An unexpected pass stimulates an immediate defensive blink as the ball almost hits her in the face (fig. 4-3). She catches it, locates a player near the basket, and keeps her eyes on that player while dribbling the ball and running closer for an easier pass.

Fig. 4-3

She walks back to her apartment and drives her car to a drive-through fast-food restaurant to pick up a quick dinner. Spatial orientation requires efficient perception of the size of her moving car in relation to the narrow lane between the building and curb. Ambient vision again plays an important part in efficient awareness of the entire road, especially the peripheral visual field where cars, bicycles, or people may suddenly appear. She uses rapid gaze shifts to scan her central visual field as well as the rearview and side mirrors.

Before going home she stops at the supermarket to buy food. She shifts gaze from her shopping list to scan the shelves, localize each item, and watch her hand as she places it in the cart. Visual monitoring of the hand is required again after the groceries are brought home and are placed in the refrigerator and cupboards.

She relaxes and watches television before going to bed, using prolonged fixation in near space to thread a needle and sew a button on a shirt to wear the next morning (fig. 4-4). She is able to follow the television program at the same time, with gaze shifts (within different focal lengths), from her sewing to the screen. A tremendous variety of visual skills have been utilized during a typical day in the life of this normal young adult.

Fig. 4-4

Visual Components of Reading

Civilization has changed man's survival meridian from the horizon to the printed page (Barsch 1968).

Learning a primary spoken language requires no deliberate instruction. It is absorbed informally and unconsciously as the child is repetitively exposed to a wide range of stimuli. Learning to read, however, is formal and structured, as strategies are taught for solving problems of recognition and meaning. Graphic sound symbols trigger a recall of meanings or help construct new meanings based on past experiences and conceptual development. Word calling without comprehension is not reading. However, in order to read efficiently with comprehension, the visual-motor and visual-perceptual elements must be well developed and integrated.

Reading, like perception, is a game of prediction, of making educated bets on past experiences. The good reader uses minimal cues to read each word and predict what the succeeding words might be, without having to reconstruct every single one. The good reader also "chunks," or reads in word groups. Older readers chunk in phrase units, organized in accordance with the meaning. Thus the fixation span is not a constant number of words, but rather shrinks and expands to accommodate the phrase boundaries (Forrest 1978).

Eye movements in reading are characterized by a series of gaze shifts, (saccadic) movements interspersed with fixation pauses. A saccade is a rapid change of fixation from one point in the visual field to another. It has been described as a jump, or thrown movement, of the eyeball, initiated by a contraction of one set of muscles that proceeds on its momentum until stopped by the contraction of an opposing set of muscles. It is almost certain that no information is obtained from the printed page, which is blurred, during the rapid movements, but only during the fixations when a variable number of letters on either side of the fixation point are perceived. Only four or five letters immediately around the fixation point are seen with 100% acuity. Letters and words outward from that point show decreasing clarity. For example, words more than a half inch from the fixation point (about a four-degree angle, when reading distance is the usual 14-16 inches) are seen with one-third of normal acuity (approximately 20/60). Approximately 93% of total reading time is spent in pauses and only 7% in eye movements. Each fixation lasts about three-tenths of a second. Variations occur depending on the difficulty and interest of the material. Prolonged fixations may occur at the end of each line of a poem (a whole second), as if what has been read is being analyzed, or any time during the reading of prose. The more complex and numerous the thoughts and ideas, the longer the fixation.

Skill in fixation (ability to fix the eyes at the place that gives a total view) and in saccades (ability to shift accurately and smoothly from one object to another) increases the speed and control of scanning (visual inspection) for obtaining the greatest amount of information with the least time and effort (Farrald and Schamber 1973; Taylor 1965).

Most adults read at a speed of fewer than 300 words a minute. In normal reading, the eyes move together in conjugate deviations and vertical deviations are minimal. Occasionally, the eyes may regress or return to previously scanned material. Good readers show as few as zero to seven regressions per line. Children with learning disabilities have been found to have more fixation points and more regressions than normal children. Academic achievement has been correlated with fewer regressions, shorter pause durations, and increased pause frequency (Yarbus 1967; Alpern 1969; Goldberg and Arnott 1970).

Table 4-3 contains results of a 1957 study of the reading skills of 5,000 students by Taylor (1960), who later established national norms using the Reading Eye, an instrument designed to measure ocular motor movements by reflecting infrared light off the corneas of the subjects' eyes. A pair of independent photo cells sense the reflections and emit signals that are recorded on heat-sensitive graph paper.

The Transdisciplinary Process

Theories of visual function addressed thus far have included those from the fields of education, psychology, medicine, anthropology, and child development. The synthesis of this information and its subsequent use for purposes of assessment and management occurs through the problem-solving process of the transdisciplinary team, which culminates in truly consensual decisions.

In multidisciplinary and interdisciplinary models, team members conduct their own intervention programs in isolation and communication between

TABLE 4-3
Assessment of Skills in Reading

Grade	1	2	3	4	5	6	Junior High	High School	College
Fixations per 100 words	240	200	170	136	118	105	95	83	75
Regressions per 100 words	55	45	37	30	26	23	18	15	11
Mean duration of fixation (seconds)	0.33	0.30	0.26	0.24	0.24	0.24	0.24	0.24	0.23
Mean rate of understanding (number of words per minute)	75	100	138	180	216	233	256	296	340

Source: Taylor 1960

members varies from a little to a great deal, but the transdisciplinary model releases intervention roles to one or two primary facilitators, and reciprocal communication among all team members is integral to the success of the program. These facilitators can be chosen according to each child's needs, the team member competencies, practical budget realities, and legal requirements (McCormick and Goldman 1979). This more holistic approach, stressing role release and role exchange, fosters intervention implemented across all disciplines, facilitates integration of visual function into all program activities, and becomes a transaction among all team members, who include professionals, paraprofessionals, and parents.

Comparisons of interdisciplinary and transdisciplinary approaches define the former as emphasizing the contributions of individual professionals and the latter as stressing collective problem solving around the child's specific needs (Meeth 1978). The process is especially appropriate for rural communities, where school districts can provide comprehensive services for children with low-incidence handicapping conditions only by forming special education cooperatives to share the limited hours and numbers of professionals (McCormick and Lee 1979).

The holistic approach to management of children with handicaps has directed the attention of the many different team members toward a primary focus: optimal human performance within as normal an environment as possible. For example, the occupational therapist and developmental/behavioral/functional optometrist have discovered common goals and compatible objectives. The optometrist no longer views vision as simply the eye working like a camera but rather as a complex sensorimotor process. The primary goal is to achieve comfortable vision that allows efficient performance in the home, classroom, workplace, and other locations in the community. The occupational therapist, aware of the many components of sensorimotor integration, works to improve those components that are essential for optimal function in occupational roles. Both professionals analyze vision problems from either developmental or functional aspects. Insufficient neural development may originate primarily from the visual system or from a general dysfunction of the central nervous system. Functional problems are those caused by the body's adaptation to biologically unacceptable stress, manifested by ocular and other difficulties. Treatment of the visual dysfunction is considered in terms of daily living needs and age-appropriate activities by both the optometrist and the occupational therapist (Hellerstein and Fishman 1987).

The College Student's Learning Process

The knowledge, skills, and attitudes necessary for productive problem solving by the professional team working with an individual with developmental disabilities can be compared to those of the college student involved in the normal learning process of transition from childhood to adulthood.

Knowledge. The student needs to absorb information about the self, the environment, and the options for becoming a productive member of society. Vision is one of the most important sensory channels for this observational process. The student attends classes, completes assignments, and seeks practical experience by living independently and being

responsible for himself or herself at home, in school, and in the community.

The professional team member needs to know and understand general and specific information about the disabled child's medical condition, visual status, and educational skills. Intervention methods and techniques must be considered in terms of the child's special abilities, limitations, and needs, and according to goals and objectives, including visual components, selected by the entire team.

Skills. The student participates in classroom discussions, writes papers on a variety of subjects, and takes tests to measure the quantity and quality of information absorbed and integrated. He or she receives positive and negative feedback from the instructor, which leads to revisions and other adjustments. Visual skills are crucial for memory recall, ability to perceive interrelationships among sets of facts, and constant organization of new material.

For the disabled child, the team member determines problem areas, selects appropriate evaluation instruments, helps plan an intervention program incorporating visual procedures, and continually re-evaluates, adapting and modifying the program in response to continuous feedback from the child's responses and intrateam discussions.

Attitudes. The student learns to develop *patience* and perseverance through the long process of discovering his or her own strengths and weaknesses. The student learns the importance of *honesty* and *trust* in relationships with others, without relinquishing the basic responsibility for his or her own future. A *humble* awareness of the need for continual learning to keep up with new knowledge in a quickly changing world is coupled with the *courage* to risk new experiences and to change from a dependent to an independent learner. The student *hopes* to be able to function independently, confidently, and successfully within his or her own personal limitations.

The team member for the disabled child displays *patience* by providing a therapeutic environment for the child to learn at his or her own rate and in his or her own style. *Honesty* involves seeing the child as he or she really is, without limiting the child's potential or setting unrealistic expectations for the child's progress. As many options are explored and the child is introduced to a series of appropriate new tasks, *trust* in the child's caregivers and the self increases. An attitude of *humility* is consistent with the team member's realization that much more needs to be learned about the child and ways to help him or her. Finally, the *courage* to try new ideas despite the risk of failure is renewed by the progress that the child has made, and *hope* is reaffirmed (Erhardt 1982; Mitcham 1985).

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PART TWO:

A Developmental Vision Assessment

Chapter Five
Evolution of the Assessment

Vision is not a mechanical recording of elements,
but rather the apprehension of significant structural pattern.
(Arnheim 1974, 6)

The Need

The evaluation and treatment of eye-hand coordination problems in developmentally disabled children who show delayed and abnormal functional vision within their total patterns of motor dysfunction differ from evaluation and treatment of those with a primary condition of low vision, blindness, or sensory-integrative deficits affecting their visual-vestibular postural mechanisms.

Traditional approaches to the study of vision have emphasized either the medical model of pathology concerned with visual acuity (distinguishing detail) or the educational model of cognitive processing concerned with visual perception (extracting information from visual stimulation). Relatively little information is found in the literature concerning the motor components of the visual action system, particularly the process of eye-hand linkage, which influences the development of both eye and hand function (Erhardt 1987).

Pediatric therapists working with developmental and/or neurological conditions such as cerebral palsy have become dissatisfied with existing tests because of insufficient items, failure to assess quality of performance, inappropriateness of design for severely involved and very young children, and limited use for structuring intervention programs (Lewko 1976). The greatest limitations of most scales relate to the size of steps between the behavioral sequences leading to emerging skills, the rate of skill acquisitions, and the influence the acquisition of a new skill has on a previously acquired one (Mira 1977).

Developmental approaches to evaluation and treatment are found to be useful, especially for those with delayed and/or abnormal prehension patterns (Erhardt 1982). Since all children, with or without disabilities, develop within a framework of predictable progressive stages, early reflexes and primitive movement patterns provide the foundation for more voluntary refined movements, and each step in the sequence of motor development depends on the integration of the preceding steps (Erhardt, Beatty, and Hertsgaard 1981). Thus, an evaluation instrument that is consistent with the principles of motor development should include sequences of reflexive and voluntary age-appropriate skills and provide not only descriptive developmental levels but also prescriptive data for intervention purposes. Such an instrument would be similar to curriculum-based assessment, which reflects a direct congruence among testing, teaching, and progress evaluation (Bagnato, Neisworth, and Capone 1986).

A handicap-specific instrument systematically identifying which skills are fully integrated, which are emerging, and which are missing generates information that can be used to design an individualized program for Individualized Program Plans (IPPs), Individualized Family Service Plans (IFSPs), or Individualized Educational Plans (IEPs).

Individuals with cerebral palsy and other developmental disabilities have visual-motor problems related to abnormal motor patterns throughout the body. Those with spasticity have muscle imbalance, limited range of motion, and slow, difficult movements of eyes as well as arms and legs. Athetosis causes fluctuations in muscle tone and irregular movements throughout the body. Visual-motor developmental levels are often consistent with gross- and fine-motor levels in children with central nervous system dysfunction.

In addition, when enormous amounts of energy are channeled into the motor components of vision, very little is left for cognitive processing of sensory input. In other words, higher-level cortical thinking becomes more difficult when normally subcortical functions require voluntary attention (Barsch 1968). The visual system, in normal children and adults as well as infants, fatigues rapidly but is capable of rapid recovery. Therefore, the professional must be alert, especially during testing sessions, to adaptive-stress behaviors such as yawning, eye rubbing, blinking, thumb or finger sucking, eye rolling, and/or withdrawal (face turning or even body turning). These signs of visual fatigue indicate the need for resting periods or ending the activity.

Vision is an interactive process of both sensory and motor components of the central nervous system, a process that is influenced by maturational mechanisms. Although growth is a continuous process subject to individual variations, it can be divided into designated, separate levels of growth, which when used as a frame of reference and orientation can serve as a guide for understanding development. Comparisons of normal, delayed, and abnormal visual development are particularly helpful in identifying the maladaptative compensations in children with multiple disabilities. The developmental approach broadens the scope of assessment and intervention by shifting emphasis from visual acuity to how visual functions are dynamically organized in relation to the total action system (Gesell, Ilg, and Bullis 1949).

The First Revision Process

Motivation to create the first developmental checklist of visual-motor skills came from a presentation by a team of professionals (therapists, educators, and optometrists) at a national conference of The Association for the Severely Handicapped (TASH) (Blackwell, Britz, and Rock 1983). The four-page Erhardt Developmental Vision Assessment (EDVA) contained 65 test items arranged at monthly intervals from natal to six months, an average of about nine components for each age level. A number of children demonstrated significant gains in visual function during treatment programs derived from the assessment process, and the test was used in the author's private practice from 1983 to 1986. At that time, after an extensive literature review of journals and books in the fields of medicine, education, child development, and developmental psychology, the test was expanded to a 16-page booklet containing 245 components derived from approximately 30 references. Test behaviors were described at monthly intervals from fetal to six months, when primitive visual reflexes are integrated and essential eye movement components are nearly as functional as in the mature adult. The six-month level was used as an approximate norm for assessing older children since it is considered a significant stage of maturity in visual-motor development. After this level, further efficiency is gained through experience and interweaving with the cognitive and motor action systems (Peiper 1963; Mussen, Conger, and Kagan 1969; Hatfield 1979; Hoyt, Jastrzebski, and Marg 1983).

The assessment was organized into two main sections:

> Section 1. **Primarily Involuntary Visual Patterns** (reflexive), consisting of three clusters: 1.a. pupillary reactions, 1.b. doll's eye responses, and 1.c. eyelid reflexes.
>
> Section 2. **Primarily Voluntary Eye Movements** (cognitively directed), consisting of four clusters: 2.a. localization (visual approach), 2.b. fixation (visual grasp), 2.c. ocular pursuit (visual manipulation), and 2.d. gaze shift (visual release).

The EDVA contained a large number of items at each level, finely graded into small enough increments to enable recording of change despite the slow development of children with multiple handicaps. Selected items were illustrated for clarity. The test booklet included instructions for administration, materials, and scoring as well as references.

Test items were designed to measure only visual responses to stimuli, with few cognitive requirements, especially at the earliest levels. Thus, testing

of infants or severely retarded individuals did not depend on "cooperation" of the subjects. Test materials could be adapted, however, to be age appropriate as well as developmentally appropriate for older children and adults. For example, suggested materials to measure localization to sound could include rattles for infants, music boxes for children, and jiggling car keys for adolescents. Duration of fixation could be measured with black-and-white patterns for infants, color drawings for children, and topical photographs for young adults. Ocular pursuit could be tested with a variety of targets selected according to subjects' age, gender, and special interests (dolls, sequined gloves, model cars, etc.). Gaze shifts were stimulated in young children by alternating internal movement between two or more targets such as finger puppets, and in older ones by requesting them to look at specified faces, such as parents, placed strategically in the same focal length or different focal lengths.

A concurrent study of reflexive and voluntary eye movements in five normal infants videotaped monthly from birth to six months corroborated the developmental sequences extrapolated from the literature (Erhardt 1986).

Several revisions of the EDVA were made during the author's extensive clinical use of the instrument in infant and preschool programs, urban school systems, and rural special education cooperatives, and the test was distributed nationally in conjunction with instructional workshops. Informal feedback was solicited and received from professionals using it in their respective programs.

The Interrater Reliability Study

The need to determine whether the EDVA was a reliable test of visual-motor function for children with developmental delays, cerebral palsy, and other motor impairments led to an interrater reliability study implemented in the fall of 1986.

Subjects. The 20 raters, all residents of North Dakota, were professionals from a variety of disciplines who had participated in a five-day workshop that provided training for administration of the EDVA. None of the raters had previous experience with the assessment. Their years of experience with the multiply handicapped population ranged from one to fourteen years, with an average of seven and a half years. Eight held master's degrees, eleven bachelor's, and one an associate degree in the professions of occupational therapy, physical therapy, speech pathology, and special education. Several had additional certification in the visually impaired or combinations of occupational therapy and psychology, special education and social work, and so on. They were employed in infant, preschool, and school programs (including some residential schools) as clinicians and teachers, and in various college and university departments of special education and occupational therapy as professors and clinical supervisors.

Procedures. Rater training during the workshop included the following:

1. Observation of a videotaped presentation of normal visual development in five infants filmed monthly from birth to six months
2. Participation in a lab experience of normal and abnormal visual developmental sequences
3. Observation of the visual-motor function of two normal infants under six months of age
4. Explanation and discussion of administration, scoring, and interpretation of the EDVA, illustrated by a videotape of a young child with severe multiple handicaps
5. Participation in a lab experience of intervention techniques
6. Explanation and application of a model for visual function in the child's total environment
7. Demonstration of the use of the EDVA for assessment and treatment of a young child with moderate handicaps
8. Small group experiences in scoring the EDVA to assess and treat children with mild, moderate, and severe handicaps.

Method. A 21-year-old college student with moderate cerebral palsy had been videotaped while being tested by the principal investigator (test author), who then reviewed the 100-minute tape and scored 212 test items in the EDVA protocol booklet. Following the workshop, all 20 raters received detailed instructions, viewed copies of the same videotape, and recorded their independent scoring judgments in copies of the test booklet. The use of the VCR pause function was encouraged, as well as

repetitions (simulating real testing situations), to allow closer scrutiny of brief scenes and avoid some of the problems of previous studies involving videotapes (Erhardt, Beatty, and Hertsgaard 1981).

Results and discussion. Each rater judged whether a given visual-motor skill was present (+), emerging (±), absent (–), or a transitional pattern replaced by a more mature pattern (++). A comparison was made of the agreement of these judgments with the scoring of the test author.

Intraclass correlations for each cluster were found using all pairs of judgments for that cluster, including the test author, that is, all combinations of two of the 21 raters on each cluster. These averaged at 0.535, and all correlations were significant to the 0.001 level.

A test item analysis used a four-point scale for the four symbols, and compared the scores assigned to all of the test items by each of the raters to the scores assigned by the test author. Nine of the 20 raters agreed with the test author on over 90% of the items; fourteen raters agreed with the test author on over 75% of the test items.

A summary of the agreements between the raters and the test author, and the intraclass correlations for each cluster are given in Table 5-1.

TABLE 5-1
Interrater Reliability of the EDVA

Cluster	Average Percent of Agreement	
	Raters with test author	Intraclass Correlations
1.a. Pupillary reactions	63.40	.02
1.b. Doll's eye responses	85.60	.74
1.c. Eyelid reflexes	86.60	.63
2.a. Localization	86.30	.67
2.b. Fixation	77.50	.59
2.c. Ocular pursuit	77.20	.52
2.d. Gaze shift	80.10	.58
Entire Test	80.90	.54

Source: Erhardt, Beatty, and Hertsgaard 1988

Statistical results of the single test item correlations were analyzed to differentiate high-reliability items from those with low reliability. Some of the low reliability (especially in 1.a. pupillary reactions in the first cluster) was attributed to problems related to the videotape, based on comments of the raters. These problems included: (1) obscured or partially obscured eyes because of shadows; (2) reduced tape quality because of the fourth generation (the VHS master was edited to ¾", then dubbed to VHS, then copies were dubbed and distributed to all raters); (3) inconsistencies in the quality of the playback machines (causing jumpy, fuzzy pictures on some); and (4) machine operation expertise of raters (the reported obscuring bands of "noise" appearing during pause could have been easily moved down to clear the picture by moving the frame advance or adjusting the tracking mechanism).

Items with low reliability were also critically examined for imprecise definitions, excessive number of components, and problems of subjective judgment. This information, together with written comments of the raters and informal fieldtesting feedback, was used to clarify, alter, or delete items with low reliability for the current revision of the EDVA. Although the interrater reliability procedure was helpful in developing the instrument for use as part of a battery of tests and as an aid to individual treatment planning, it should not be confused with test-retest reliability or considered a standardized assessment tool until validity is established (Erhardt, Beatty, and Hertsgaard 1988).

Current Version of the EDVA

The organizational structure of the revised 1989 EDVA remains unchanged. Instructions have been expanded to include new, more specific information about positioning, illumination, stimulus materials, and administration. A scoring example has been added to demonstrate the procedures.

Totally new illustrations have been created to replace the diagrammatic drawings in the 1986 EDVA. Item components were increased to 271 from 245, and the test language revised to be more concise and precise. Specification of fields, direction, or eyes in relation to scoring of left/right function has clarified an area of previous confusion. Finally, the addition of scoring during occlusion of one eye has provided the opportunity for gaining more complete information about monocular and binocular use of vision.

Evaluation of the EDVA

The EDVA, which measures visual-motor development, is an instrument that should be reviewed and evaluated for quality and appropriateness.

Marked deficiencies have been found in many tests measuring motor function, particularly in the accurate identification of different levels of function (discriminant validity) and both types of reliability (interobserver and decision making). *Discriminant validity* measures the extent to which the scale discriminates between groups of children and degrees of their motor dysfunction. *Interobserver or interrater reliability* refers to the degree to which different persons observe the same behavior. Ideally, the observations of one should coincide with those of the others, and the observed performances should be virtually identical. The interrater reliability coefficient should exceed 0.80, indicating a high degree of objectivity. *Decision-making reliability* focuses on the consistency or dependability of the instrument.

Specific criteria useful in assembling motor scales were assembled into a checklist of questions (Berk and DeGangi 1979). The answers to these questions may serve to give a general indication of the EDVA's quality and appropriateness for use with handicapped children.

Validity

1. ***Is the domain of motor behaviors to be measured by the scale defined clearly? Do the items provide a representational sample?***

Since the EDVA attempts to include nearly *all* visual-motor behaviors within its defined parameters, the problem of determining a representational sample is nonexistent.

2. ***Are the domain specifications comprehensive, are major constructs or dimensions of motor behavior identified, and is statistical evidence reported to support the structure and organization of the scale?***

The organization and hierarchy of the EDVA are based on a sound theoretical foundation, and detailed descriptions and illustrations define each pattern component. However, studies are needed to provide statistical evidence of construct validity.

3. ***Do the items on the scale measure the motor behaviors?***

All behaviors are included in the EDVA and thus are measured directly by observation of the child's responses.

4. ***Is the scale appropriate for the intended use and population, and are cutoff scores recommended for identification of degrees of motor dysfunction supported by rationale and statistical evidence?***

Informal feedback reports indicate that the EDVA is extremely appropriate for individuals with developmental delays or dysfunction. Discriminant validity studies are needed, however, to identify persons for appropriate treatment programs.

Reliability

5. ***Is an index of interobserver or interrater reliability agreement reported?***

A complete report of an interrater reliability study is presented. Percent of agreement of the raters with the test author for the entire test averaged 80.9%.

6. ***Does the index indicate the scale can be administered, scored, and interpreted objectively?***

Intraclass correlations averaged 0.535, and all correlations were significant to the 0.001 level.

7. ***Does the index indicate the decisions made with the scale would be dependable?***

Test-retest reliability studies are needed to determine the consistency of the EDVA.

Considerations for Administration of the EDVA

Assessment of skills in children with significant handicaps, especially those with a slow rate of development as well as visual impairments, presents special difficulties. Very small changes must be measurable, as fewer channels of communication are available, and the number of test items is usually restricted. Responses may be inconsistent, delayed, performed in certain settings only, or after considerable prompting or assistance. Important variations of response may not be recorded when a binary scoring system (correct or incorrect) is used. Alternatives to binary scoring include a Likert scale (allowing judgment of different degrees of response correctness), a multidimensional system (evaluating each response for the degree of completeness, promptness, need for assistance, accuracy, etc.), and

a developmental sequence (identifying a series of graded steps leading to a specific functional task).

Each of these alternative scoring systems are more sensitive to small changes in behavior and can be useful for assessment of very low-functioning children, for whom change occurs slowly and in small increments (Erhardt 1982; Cole et al. 1985). Two standardized developmental tests, the Peabody Developmental Motor Scales and the Battelle Developmental Inventory, include a method of allowing credit for partial responses that do not meet item criteria of pass or fail (Fewell and Sandall 1986).

Selection of instruments depends on the outcomes to be measured in terms of intervention objectives that address not only deficits, but also adaptive behaviors (Mott et al. 1986). Professionals have struggled with the choice and use of assessments for children with multiple handicaps. Standardized tests, which provide actual developmental levels, are necessary for qualification of an individual for special services and quantification of subsequent gains. These data, however, have often been used to generate IEP goals and objectives, despite documentation that it is virtually useless for that purpose or for designing intervention procedures. A technically good test item is not automatically an important learning task, integral to success in life skills. Standardized tests are not meant to provide information as to why a child fails an item, nor clues for facilitating success.

Potential for future learning can better be assessed by measuring the zone of proximal development, described by the psychologist Vygotsky (1978) as the distance between the actual developmental level and the level of potential development when facilitated by certain interactions with people. Intervention based on nonstandardized tests allows administrative procedures that are useful in defining the zones of proximal development. Those procedures include selected verbal and nonverbal cues and/or demonstrations to increase the child's problem-solving skills and thus the level of performance. This method of evaluation determines the most effective intervention approach to actually stimulate maturing (emerging) capacities that are in the early stages of development rather than absent. Assistance and facilitation can include adapted positioning to provide stability/mobility and modification of materials and type of stimulus (size, speed, and content). Any functional tasks that a child can accomplish with assistance but not independently can be considered within his or her zone of proximal development (Lyons 1984; Wilcox 1986).

Evaluation of visual function cannot be an isolated procedure since individuals use their vision in a variety of ways depending on their immediate environment, emotional and physical states, previous experiences, and style and rate of learning. The most valid information is derived from ongoing assessments in natural environments. Clinical observations of behavioral reactions are most useful in planning intervention procedures when the sequences of developmental tasks are broken into small enough steps so that a realistic profile of the child emerges. The team can use that information, combined with other diagnostic and clinical data, to determine the appropriate initial level of prescribed activities (Barraga 1976). Continual adjustment of objectives, materials, and strategies is dependent on formative, ongoing feedback that not only assesses the child's performance, but also modifies instruction. Developmental curriculum-based assessment thus provides clear data of fully acquired and emerging skills and needs, methods for designing an individualized program, and a reliable measure of the content validity of the instrument (Bagnato, Neisworth, and Capone 1986).

Prior to assessment the following questions need to be considered:

1. What is the purpose of assessment?
   To prove eligibility for service?
   To determine present level of function?
   To establish a baseline level?
2. Are definitive functional norms or age-level equivalents needed?
   Are criteria used for the assessment process related to what is realistically present?
3. Can the assessment procedure determine whether low levels of function are due to lack of experience and opportunity or diminished physical or mental learning capacity?
   Or are higher levels identified due to enriched experiences or greater learning capacity?
4. Are inappropriate responses or behavior due to visual problems or neurological/learning problems?

Inaccurate assumptions can be made during the testing of vision. Evaluators need to be alert to the factors presented in Table 5-2.

TABLE 5-2
Factors Leading to
False Positives and Negatives in Vision Testing

False Positives (visual function normal, but impairment suspected because of lack of response)

1. Fatigue or boredom with subject or examiner
2. Use of uninteresting or unfamiliar stimulus
3. Use of same stimulus repeatedly
4. Placement of stimulus in incorrect position
5. Subject too preoccupied tactilely or auditorially
6. Examiner insensitive to minimal or delayed responses

False Negatives (visual function impaired, but not detected because approximate responses are observed)

1. Subject alert to auditory properties of visual stimulus
2. Subject responds to examiner's sounds or touches
3. Subject responds to air movements
4. Examiner interprets chance eye movements as response
5. Examiner gives clues by facial expression or own directional eye movements

Source: Holt 1977

The EDVA-S: A Short Screening Form

Although ophthalmologists have advocated periodic professional eye examinations for all children early in life, the National Society to Prevent Blindness has recommended, for realistic reasons, vision screening for newborns before leaving the hospital (especially those in intensive care units), infants at six months of age, and preschool children, ages three to five. Abnormal findings observed during any aspect of screening indicate referral for a complete diagnostic ophthalmic evaluation.

Screening tests at different ages may include the following:

1. External inspection for abnormal appearance of the eyes, indicating infection, trauma, or congenital anomalies
2. Observation of the eyes operating separately and together for deficient pupillary responses, deviations, nystagmus, cataracts
3. Intraocular examination of optic nerve and retina with ophthalmoscope
4. Estimation of visual development (interest in near objects) and appreciation of movement (of far objects)
5. Visual acuity tests (Hatfield 1979)

The EDVA-S may be used as a quick screening test for persons from the age of six months through adulthood. Each cluster of the EDVA-S contains the test items designated as norms in the EDVA (shaded scoring circles, under pattern components). These permanent patterns continue throughout life, as opposed to transitional patterns to be replaced by more mature patterns. The total number of norm components is 67, compared with 271 items on the entire test. If *all* norms in an EDVA-S cluster are scored + (well integrated, normal), then that cluster of skills can be considered intact. If *any* norm in a cluster is scored – (not present) or ± (emerging or inconsistent), then the entire cluster needs to be scored with the EDVA for more in-depth assessment. This research edition of the EDVA-S is presented as a preliminary version, yet to be fieldtested. Future reliability and validity studies are planned to lead to standardization.

The current version (1989) of the Erhardt Developmental Vision Assessment (EDVA)© is presented in the following pages, followed by the EDVA-S (Short Screening Form).

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Erhardt Developmental Vision Assessment (EDVA) ©

By Rhoda P. Erhardt **Illustrated by Gary Baune**

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SECTION 2. Primarily Voluntary Eye Movements (Cognitively-directed)
SUMMARY

Subject: _____ **Examiner:** _____

Birthdate: _____ **Chronological Age:** _____ **Test Date:** _____

Diagnoses: _____

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INSTRUCTIONS

Organization and Rationale

Protocol Sheets group the components of vision into Developmental Sequence Clusters, and demonstrate how transitional skills at each age level lead to those at the next. Section 1 and 2 measure vision development from the fetal and natal periods to 6 months, when primitive reflexes are integrated and essential eye movement components are nearly as functional as in the adult. The 6-month level can be considered a significant stage of maturity in visuo-motor development, and thus an appropriate norm for assessing older children and adults with developmental disabilities. Increased skill in localization, fixation, ocular pursuit, and gaze shift are gained in normal development through further experience and interweaving with the total cognitive and motor action system.

Positioning

Testing should be done in each subject's most stable functional position, ordinarily sitting or semi-reclining. Other positions which may be appropriate include supine, prone, sidelying, or standing, with or without adaptive equipment.

Illumination

Room and stimulus illumination should vary according to specific test items and subjects' individual needs. Lighting may range from very subdued (for items involving a focalized light stimulus and for subjects whose photophobia is due to chronological or developmental immaturity), to very bright (for subjects with low or minimal vision). Additional mild illumination (red light) of other eye may be needed for observation of the Consensual Light Reflex (1.a.): Darkened backgrounds in illustrations indicate the need for subdued illumination, particularly at all Fetal and Natal levels.

Materials

Appropriate test materials should be selected according to each subject's age, gender, cognitive, cultural, and personal interests, with enough novelty to avoid satiation or habituation. Information regarding developmentally- and age-appropriate stimuli will be determined from Clusters 2.a. and 2.b., and may be used for 2.c. and 2.d. At least one identical paired set of stimuli for each category (light, sound, movement, contour/pattern, etc.) should be included as well as test booklet, pencil with eraser, and adjustable eye patch for occlusion of each eye.

Inanimate Visual

- Light sources: penlight, flashlight, lamps, Xmas tree lights (focalized); window areas (diffused)
- Targets which glitter when illuminated: gold or silver jewelry, crumpled foil, Xmas swags, prisms
- Targets with pattern and/or color: black and white stripes and bull's eyes, fluorescents and bright colors (red, orange, yellow)
- Targets with contour: motionless persons, dolls, stuffed animals (3-dimensional); pictures, books, photographs, alphabet letters, and numbers (2-dimensional)
- Tiny targets: edible and non-edible pellets

Inanimate Auditory

- Targets with sound attributes only: bells, music boxes, squeak toys, toy horns, whistles, non-visualized human voice, radio, or tape recorder

Animate Visual

- Targets with internal movement only: puppets (hand, finger, stick), dangling mobiles, pinwheel, slinky, mirrors, flutterball, non-vocalizing faces, sequined glove, enclosed glass snow scene
- Moving targets without sound: balloons, soap bubbles, balls, pompoms

Animate Visual and Auditory

- Targets with both sound and movement: rattles, wind-up and battery-operated toys, music boxes, car keys, metronome, vocalizing faces

Administration

Unless videotaped, the test should be administered with the help of an assistant (other professional, paraprofessional, or parent) to share the multiple tasks of presenting stimuli, observing visual responses, and recording scores. Examiners should be alert to the visually distracting effects of strongly patterned or brightly colored clothing.

The test has been designed for subjects of all ages and cognitive levels. No verbal directions are required, as each stimulus is presented and responses are observed. Some subjects may be more cooperative if the procedures are explained, e.g., "I'm going to shine this light in your eye"; others may need to be engaged in intermittent conversation to maintain attention.

Subjects who wear prescriptive lenses should remove them for testing of all reflexive patterns only.

Testing should be done with both eyes open for all items *and*, if necessary, with each eye occluded for Clusters 2.b. Fixation (to determine functional stability), and 2.c. Ocular Pursuit (to determine functional mobility). All tracking in 2.c. must be done in arcs of constant focal length to avoid requiring subject to change focus in addition to exerting extraocular muscle control.

Adequate response time should be allowed for subjects with long latency periods due to motoric dysfunction.

Periodic blink should be observed and informally recorded before formal testing to distinguish between the subject's normal blink rate and blinks related to eyelid reflexes, gaze shifts, or generalized visual fatigue after extended testing.

Scoring Procedures

A. Present stimuli and/or observe subject
B. Record Pattern Component scores in small circles according to Key B, and qualitative comments in blank page areas.

Pattern Components Key B

NA Not Applicable

⊕ Well-integrated normal pattern ⊖ Pattern not present ⊕/⊖ Emerging or inconsistent pattern
⋕ Transitional pattern replaced by more mature pattern (⊖) (⊕/⊖) Intervention needed
⊕ NORM: permanent pattern continuing throughout life ○ Pattern component illustrated

Example:

2.b. Fixation (Visual Grasp)

Developmental Levels	
Right	Left
3 months	
±	⋕

Pattern Components			Eye (other occluded)	R	L
R	L	Field (Both Eyes)			
(⊕/⊖)	⊕	Maintains fixation on non-vocalizing **face** for 10 seconds		(⊖)	⊕
⊕		Direct, discriminative **focal fixation** on target in midline		⊕	⊕
⊕	⊕	Inconsistent **Binocular Fixation**			
⊕	⋕	Maintains fixation on stationary target unless distracted by **moving** one		⊖	⋕

C. Determine and record Developmental Level Scores in large circles according to Key C, both right and left.
Developmental Level Scores should reflect scores from single circles, both eyes open, and each eye occluded.
D. Transfer Developmental Level Scores from Protocol Sheets to Score Sheet.
E. Estimate range of Developmental Levels for Score Sheet Summary.

Developmental Levels Key C

⊕ *All* pattern components present ⊖ *No* pattern components present
○ NORM ⊕/⊖ *Some* but not all pattern components present
⋕ *All* pattern components replaced ⊕ Should be transferred as ⋕

Interpretation

Pattern Components indicate gaps in skill sequences, developmentally inappropriate patterns, and specific intervention needs.
Developmental Levels measure baseline levels, identify significant delays, and provide accountability with retesting.

Section 1. Primarily Involuntary Visual Patterns (Reflexive)

1. a. PUPILLARY REACTIONS

Stimuli: Penlight (**weak** light) and Flashlight (**strong** light) directed into one eye within 12" in dimly lit room

Functional Implications: Tests rapidity of environmental adaptation since light is the first activation of the visual system

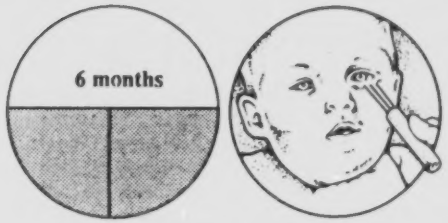
Developmental Levels	
Right	Left

Pattern Components	
R	L
Eye	

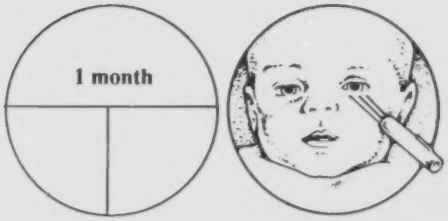
Direct Light Reflex

Pattern Components	
R	L
Eye	

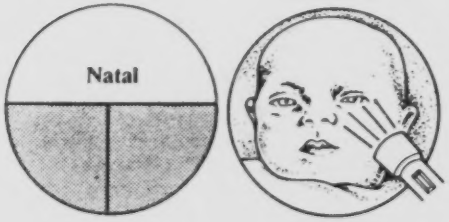
Consensual Light Reflex
(stimulation of one pupil results in equal constriction of both)



- Pupil constricts quickly to **weak** light directed into eye
- Pupil dilates quickly when **weak** light is removed from eye
- Pupil constricts quickly and equally to **weak** light directed into **other** eye
- Pupil dilates quickly and equally when **weak** light is removed from **other** eye



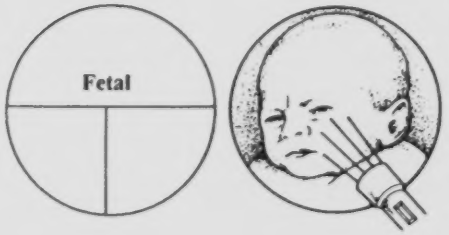
- Pupil constricts slowly to **weak** light directed into eye
- Pupil dilates slowly when **weak** light is removed from eye
- Pupil constricts slowly and equally to **weak** light directed into **other** eye
- Pupil dilates slowly and equally when **weak** light is removed from **other** eye



- Pupil constricts quickly to **strong** light directed into eye
- Pupil dilates quickly when **strong** light is removed from eye
- Pupil constricts quickly and equally to **strong** light directed into **other** eye
- Pupil dilates quickly and equally when **strong** light is removed from **other** eye

Late Stage (8-9 months)

- Pupil constricts slowly to **strong** light directed into eye
- Pupil dilates slowly when **strong** light is removed from eye
- Pupil constricts slowly and equally to **strong** light directed into **other** eye
- Pupil dilates slowly and equally when **strong** light is removed from **other** eye



Early Stage (6-7 months)

- No pupil constriction to **weak** light directed into eye
- No pupil constriction to **strong** light directed into eye
- No pupil constriction to **weak** light directed into **other** eye
- No pupil constriction to **strong** light directed into **other** eye

1.b. DOLL'S EYE RESPONSES

Stimuli: Passive movement of head against body

Functional Implications: Prepares for voluntary separation of eyes from head
Integrated when eyes and head move together voluntarily

Eyes should not be fixating on a target during the rapid passive head-turning

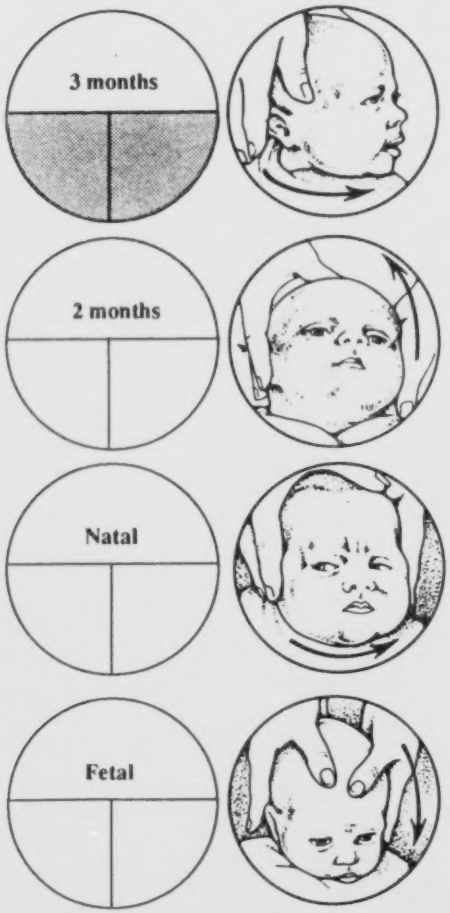
Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction	

Head Rotation

Pattern Components	
R	L
Eye	

Head Flexion/Extension



Eyes move in same direction as head **rotation**: Integrated

Eyes move in same direction as head **flexion**: Integrated

Eyes move in same direction as head **extension**: Integrated

Delayed or inconsistent eye movements in same direction as head **rotation**: Beginning integration

Delayed or inconsistent eye movements in same direction as head **flexion**: Beginning integration

Delayed or inconsistent eye movements in same direction as head **extension**: Beginning integration

Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **rotation** during first 10 days, gradually decreasing

Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **flexion** during first 10 days, gradually decreasing

Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **extension** during first 10 days, gradually decreasing

Mid Stage (7-8 months)

Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **rotation**

Mid Stage (7-8 months)

Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **flexion**

Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **extension**

1.c. EYELID REFLEXES

	Stimuli	Functional Implications
Defensive Blink to Threat	Rapid approach and removal of visualized target (Small: spread fingers; Large: test booklet)	Protects eyes from tactile assault
McCarthy's Reflex	Light non-visualized tap above one eyebrow (supraorbital area)	Activates unilateral eyelid function
Naso-Palpebral Reflex	Light non-visualized tap on bridge of nose	Activates bilateral eyelid function
Eye-Neck Reflex	Bright light in eyes, head unsupported (flashlight)	Primitive survival reaction
Visuo-Palpebral Reflex	Bright light in eyes (flashlight)	Protects eye from excessive light
Cochleo-Palpebral Reflex	Sharp noise (hand clap)	Protects eye from certain non-visual stimuli

Developmental Levels

Right	Left

Pattern Components

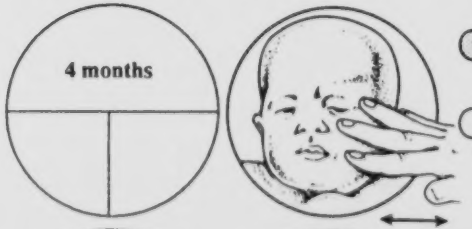
R	L
Field	

Defensive Blink to Threat

Pattern Components

R	L
Eye	

Immediate and consistent to **small** target in **peripheral** field

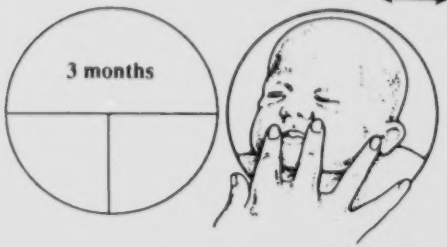


Immediate and consistent to **large** target in **peripheral** field

Delayed or inconsistent to **small** target in **peripheral** field

McCarthy's Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap

Naso-Palpebral Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap



Immediate and consistent to **small** target in **central** field

Delayed or inconsistent to **large** target in **peripheral** field

Eye-Neck Reflex: integrated in preterm infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backward)

Consistent and equal **eyelid opening** in normal illumination (both fully open)

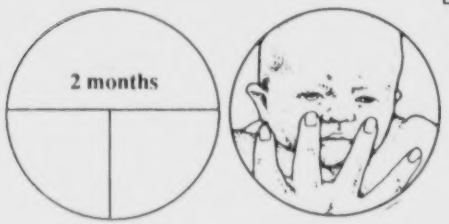
1. c. EYELID REFLEXES

Developmental Levels	
Right	Left

Pattern Components	
R	L
Field	

Defensive Blink to Threat

Pattern Components	
R	L
Eye	



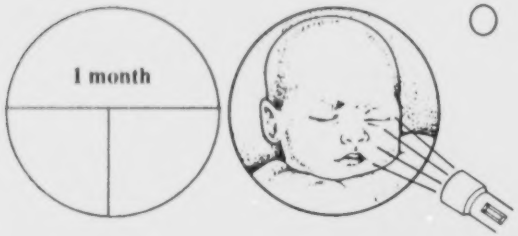
○ Immediate and consistent to **large** target in **central** field

○ Delayed or inconsistent to **small** target in **central** field

McCarthy's Reflex: beginning integration, delayed or inconsistent homolateral blink

Naso-Palpebral Reflex: beginning integration, delayed or inconsistent bilateral blink

Inconsistently equal **eyelid opening** in normal illumination

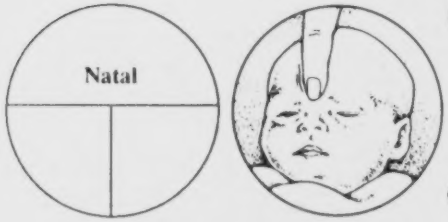


○ Delayed or inconsistent to **large** target in **central** field

Visuo-Palpebral Reflex: tight eyelid closure

Eye-Neck Reflex: integrated in full-term infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backwards)

Consistently equal **eyelid opening** in subdued light (both fully open)



Cochleo-Palpebral Reflex: blinking of both eyes without global responses

Visuo-Palpebral Reflex: blinking

Eye-Neck Reflex: opisthotonos (arching backward) strong in first week only

Naso-Palpebral Reflex: blinking of both eyes

Consistent **eyelid opening**, one wider, in subdued light

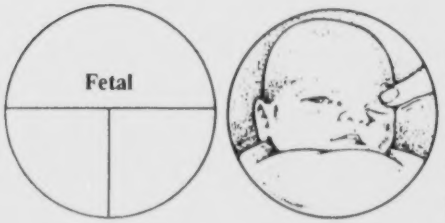
Late stage (8-9 months)

Cochleo-Palpebral Reflex: blinking and global startle

Late stage (8-9 months)

Visuo-Palpebral Reflex: eyelid tensing and flinching

Eye-Neck Reflex: opisthotonos (arching backward)



Mid stage (7-8 months)

Defensive Blink to Threat

None to **small** target in **peripheral** field

None to **large** target in **peripheral** field

None to **small** target in **central** field

None to **large** target in **central** field

Mid stage (7-8 months)

Visuo-Palpebral Reflex: strong frowning or flinching

McCarthy's Reflex: immediate homolateral blink

Inconsistent **eyelid opening**, one wider, in subdued light

Early stage (6-7 months)

Cochleo-Palpebral Reflex: mild eyelid flinching

Early stage (6-7 months)

Visuo-Palpebral Reflex: mild flinching through closed or semi-closed lids

Eye-Neck Reflex: no response

McCarthy's Reflex: one-eye flinch

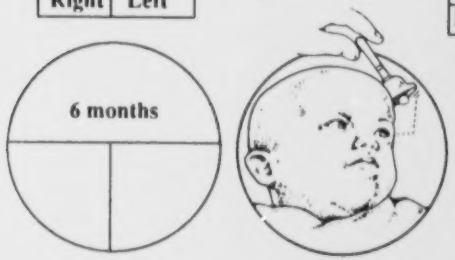
Naso-Palpebral Reflex: eyes flinch

No **eyelid opening**, even in subdued light

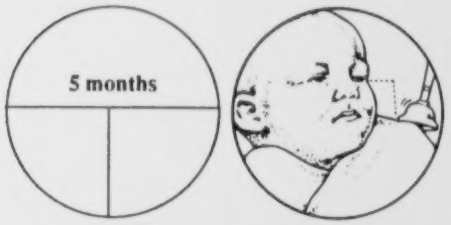
Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)
2. a. LOCALIZATION (VISUAL APPROACH)

Target Size	Focal Lengths	Stimuli
Large: bigger than examiner's hand Small: size of hand or smaller Tiny: pellet size	Near space: 3-12" Middle space: 1-6' Far space: 6-20' Distant space: 20'-infinity	Light Sound Faces Contour Movement

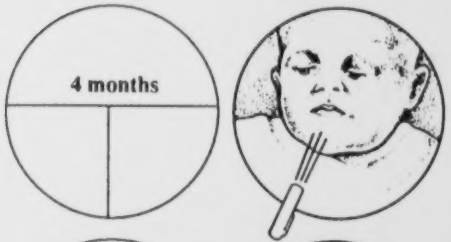
Developmental Levels		Pattern Components	
Right	Left	R	L
		Direction	



Eyes localize, then **hand** approaches and contacts tiny target
Eyes move independently from stabilized **head** to localize target
Localizes non-vocalizing **face** in far space
Localizes large target by **contour/pattern** in **far** space
Adjusts **body** position to localize target more easily
Turns to side, then up, to localize non-visualized **sound** above ear
Turns in arc movement to localize non-visualized **sound** below ear



Eyes and **hand** pursue lost small target outside visual field
Eyes localize tiny target in near space, without **hand** approach
Eyes begin to move independently from stabilized **head** to localize target
Localizes vocalizing **face** in far space
Localizes large **moving** target in **far** space
Localizes small target by **contour/pattern** in **middle** space
Turns to side, then down, to localize non-visualized **sound** below ear



Eyes localize and **hand** grasps small target in near space
Eyes, not **hand**, pursue lost small target outside of visual field
Smiles at own **face** in mirror spontaneously or when tapped
Localizes large target by **contour/pattern** in **middle** space
From side / From above / From below > Localizes **penlight** moving slowly into peripheral field in an arc 12" away at 90° from central fixation point (tested in subdued light)

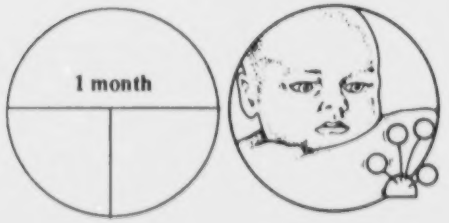
Eyes and **head** move together consistently to localize target
Eyes regard own **hand** spontaneously
Prompt regard to target presented **centrally** (in body midline)
Eyes localize and **hand** approaches, contacting small target in near space
Eyes glance briefly at target in own moving **hand**
Localizes large **moving** target in **middle** space
Eyes turn to target with sound properties placed in own **hand**
Turns toward side of non-visualized **sound** 18" from ear
Localizes non-vocalizing **face** in middle space

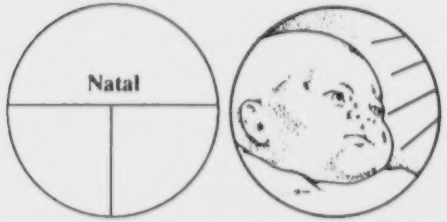
2. a. LOCALIZATION (VISUAL APPROACH)

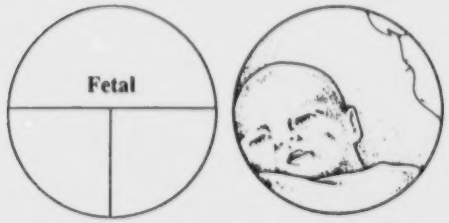
Testing localization to diffuse light: Subject is observed during slow rotation away from light, for head derotation toward light.
Testing localization of penlight moving into peripheral field from each side and above: Examiner stands behind subject who is fixating on another target at central fixation point. To test from below: Subject reclines as target is brought upward from feet.

Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction	







Eyes glance at own moving **hand/fingers**
Delayed regard to target presented **centrally** from below (viewed at chest level)
Turns to target in **peripheral** surroundings
Localizes **penlight** moving slowly into peripheral field in an arc 12" away at 30° from central fixation point
Localizes small target with internal **movement** up to **3'** away
Localizes large target with internal **movement** in **middle** space
Localizes non-vocalizing **face** in near space
Localizes vocalizing **face** in middle space
Turns toward general direction of non-visualized **sound** source

Eyes and **head** move together inconsistently during voluntary movements
Localizes diffuse **light** source
Localizes small target with internal **movement** up to 12" away
Brief glances at large target with internal **movement** in **middle** space
Brief regard of non-vocalizing **face** in near space
Localizes vocalizing **face** in near space

Random **eye** movements, not together with random **head** and **body** movements
Diffuse distractibility to target in **peripheral** surroundings
Turns toward large areas of **light**
Localizes small target with internal **movement** exactly 8" away

Late Stage (8-9 months)

Turns toward diffuse **light**
Faint interest in **peripheral** surroundings
Localizes focalized **light** (penlight) moving into peripheral field at central fixation point
Widens eyes and attends to pleasant non-visualized **sound** without head turning

Early Stage (6-7 months)

No response to visual target
No head-turning toward diffuse **light**
Involuntary **eyeball** movements in all directions, even under closed lids
Mild eyelid flinching to non-visualized **sound**
No head-turning toward focalized **light**

2. b. FIXATION (VISUAL GRASP)

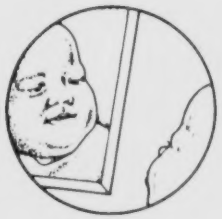
Modes of Visual Processing
Ambient: passive stare, with awareness of surroundings Focal: active focus on target, excluding surroundings

Approximate Functional Focal Lengths		
Near Space: 3-12"	Middle Space: 1-6'	Far Space: 6-20'

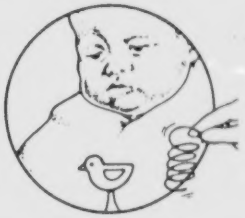
Developmental Levels	
Right	Left

Pattern Components
R L
Field (Both Eyes)

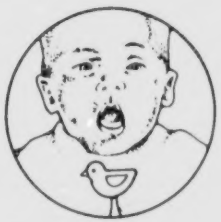
Pattern Components
R L
Eye (Other Occluded)



Intense **focal** fixation with visual responses, global suppressed
Inspects own **face** in mirror intently
Eyes fixate on tiny target while **hand** approaches and contacts
Fixates at **focal lengths**: 3" - 20'



Maintains **focal** fixation with more visual than global responses
Maintains fixation on stationary target in competition with **moving** one
Intermittent regard of own **face** in mirror
Eyes fixate on tiny target without **hand** approach
Fixates on **focal lengths**: 3" - 6'



Efficient **ambient** inspection of surroundings in middle and far space
Eyes maintain fixation on small target in **hand**
Prolonged, selective **focal** fixation with multiple global responses
Uses **ambient** starey fixation on surroundings to rest from intense focal fixation
Consistent **binocular fixation**
Eyes fixate recurrently and with delay on tiny target without **hand** approach
Fixates at **focal lengths**: 4" - 5'

Maintains fixation on non-vocalizing **face** for 10 seconds
Crude **ambient** inspection of surroundings in middle and far space
Direct, discriminative **focal** fixation on target in midline
Inconsistent **binocular fixation**
Eyes fixate briefly on small target placed in own **hand**
Prolonged fixation on target with rhythmical **movement**
Maintains fixation on stationary target unless distracted by **moving** one
Fixates at **focal lengths**: 5" - 3'

2. b. FIXATION (VISUAL GRASP)

Developmental Levels	
Right	Left

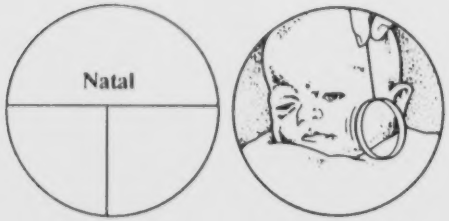
Pattern Components	
R	L
Field (Both Eyes)	

Fixation Criteria (Global responses mature to visual only)	
Global Eyes and mouth open, increased or decreased respiration, muscle tone, or body activity	**Visual** Pupils constricted, eyes round rather than oval, upper eyelids tensed and raised, eyes relatively immobile

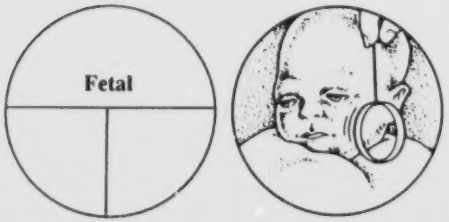
Pattern Components	
R	L
Eye (Other Occluded)	

Direct discriminating **focal** fixation on target at the side of midline
Maintains fixation on vocalizing **face** for 10 seconds
Beginning **binocular fixation** with blinking and overconvergence
Eyes regard **hand** in ATNR position (head facing extended arm, other flexed)
Fixates longer on black and white bull's eye **pattern** than stripes
Fixates at **focal lengths**: 6" - 2'

Brief **focal** fixation on target at the side of midline
Fleeting regard of non-vocalizing **face**
Brief fixation on vocalizing **face** for 2-3 seconds
Defined **monocular fixation**: active eye fixates on target, other shifts nasally
Bi-ocular fixation (alternating monocular): fixation alternates rapidly between both eyes, which shift with head in rhythmical lateral excursions
Roving eyes become relatively immobile, with **ambient** stare at surroundings
Fixates longer on black and white stripes than bull's eye **pattern**
Fixates at **focal lengths**: 7" - 12"



Tries to achieve **focal** fixation on target at side of midline, with some global responses
Vague, intermittent, **ambient** regard of surroundings
Crude **monocular fixation**: active eye aligns, tries to immobilize and fixate momentarily on target while inactive eye closes or deviates nasally or temporally
Regards target with internal **movement** placed in line of vision
Maintains **ambient** gaze toward diffuse light by turning head when slowly rotated away
Fixates longer on black and white **pattern** than on target without pattern/contrast
Fixates at **focal length**: 8"



Late stage (8-9 months)

Immobilizes eyes briefly in pseudo-fixation (diffuse, passive, **ambient**)

Mid stage (7-8 months)

Briefly alert to target with **movement** properties (agitated or dangling)

Early stage (6-7 months)

No **focal** fixation
No immobilization of eyes in **ambient** stare at surroundings
No **ambient** gaze toward light

2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

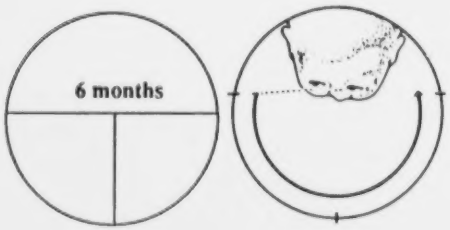
Approximate Functional Focal Lengths	
Near Space: 3 - 12"	Far Space: 6 - 20'
Middle Space: 1 - 6'	Distant Space: 20' - infinity

Compensatory Eye Movements: Eyes remain on stationary target during active head movements

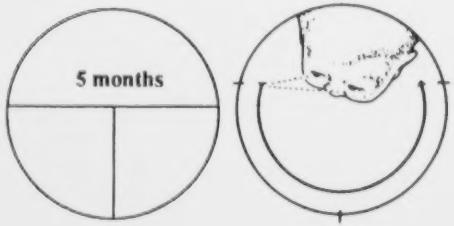
Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction (Both Eyes)	

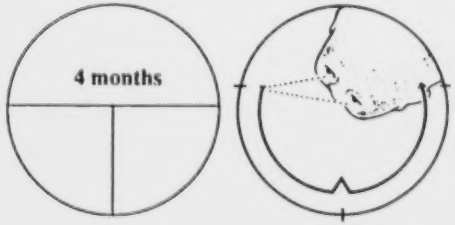
Pattern Components	
R	L
Eye (Other Occluded)	



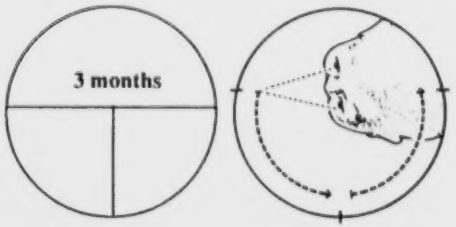
Eyes move independently from **head** to extreme right/left fields while tracking
Tracks target **horizontally 180°** smoothly at all speeds, **focal length 3" - infinity**
Tracks to **circular** direction smoothly at all speeds and focal lengths
Tracks **vertically upward** smoothly at all speeds and focal lengths
Tracks **vertically downward** smoothly at all speeds and focal lengths
Smooth **convergence** from far to near space
Smooth **divergence** from near to far space
Tracks **diagonally upward** with midline pause to refixate
Tracks **diagonally downward** with midline pause to refixate



Eyes begin to move independently from **head** to limited upper/lower fields
Tracks target **horizontally 180°** without midline jerk, **focal length 3" - 6'**
Continuous **diagonal** tracking **downward** with some jerky movements
Smooth **convergence** from far to middle space



Eyes begin to move independently from **head** to limited right/left fields
Tracks target **horizontally 180°** with midline jerk, **focal length 4" - 5'**
Continuous **circular** tracking with some jerky movements
Continuous **vertical** tracking **downward** with some jerky movements
Continuous **diagonal** tracking **upward** with some jerky movements
Smooth **divergence** from middle to far space



Tracks target **horizontally 180°** continuously, overshooting, with midline pause and re-localization, **focal length 5" - 3'**
Tracks, lingers, and visually searches for target at point of disappearance
Continuous **vertical** tracking **upward** with some jerky movements
Beginning **vertical** tracking **downward**, in series of jerky movements, losing and regaining target
Beginning **diagonal** tracking **upward**, in series of jerky movements, losing and regaining target
Continuous **convergence** with some jerky movements from middle to near space
Continuous **divergence** with some jerky movements from near to middle space
Compensatory Eye Movements: eyes remain on stationary target consistently during rapid and extensive voluntary head movements

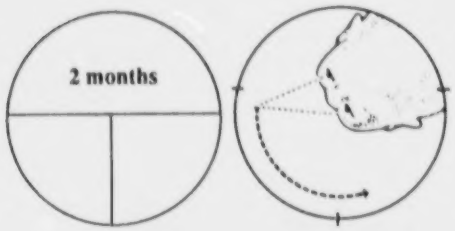
2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

Developmental Levels	
Right	Left

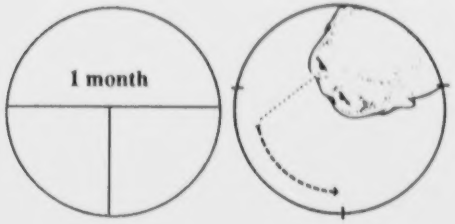
Pattern Components	
R	L
Direction (Both Eyes)	

Tracking Movements	Vergence Movements
Eyes remain on target during horizontal, vertical, circular, and diagonal movements	Eyes remain on target during convergence and divergence in all focal lengths

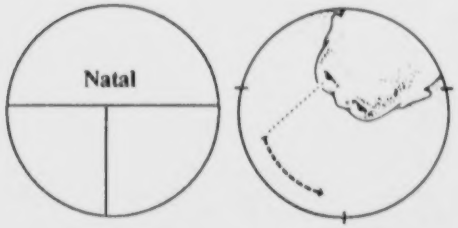
Pattern Components	
R	L
Eye (Other Occluded)	



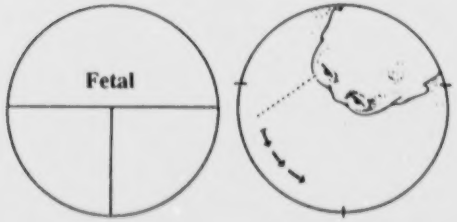
Tracks target **horizontally 90°** slightly past midline, jerky movements, poor regulation of eye speed to target speed, **focal length 6" - 2'**
Beginning **circular** tracking in series of jerky movements, losing and regaining target
Beginning **vertical** tracking **upward** in series of jerky movements losing and regainingtarget
Beginning **convergence** with short jerks, blinking, and overconvergence within near space
Beginning **divergence** with short jerks, blinking, and overdivergence within near space
Compensatory Eye Movements: eyes remain on stationary target inconsistently during rapid and extensive voluntary head movements
Follows target longer during **approach** than **retreat**



Tracks target **horizontally 60°** from periphery to midline and back to side, jerky movements, **focal length 7 - 12"**
Follows target equal distance during **approach** and **retreat**
Compensatory Eye Movements: eyes remain on stationary target during moderate speed and excursions of voluntary head movements



Eyes and **head** move together during tracking
Eyes and **head** move randomly in short lateral excursions
Tracks target **horizontally 45°** in peripheral field, in series of jerky movements, losing target frequently, difficulty regaining, **focal length 8"**
Follows target longer during **retreat** than **approach**, between 8 and 12"
Compensatory Eye Movements: eyes remain on stationary target during very slow voluntary head movements in limited range



Late Stage (8-9 months)
Tracks slowly moving target with internal movement horizontally 30° in peripheral field in near space, constantly losing target, able to regain if target pauses
Mid Stage (7-8 months)
Momentary afterpursuit of slowly moving target with internal movement (fluttering fingers)
Early Stage (6-7 months)
Eyes move without purpose, separate from **head**, even under closed lids
No response to visual target

2. d. GAZE SHIFT (VISUAL RELEASE)

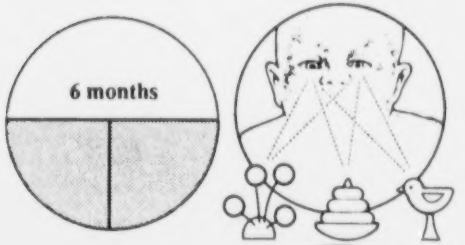
Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction	

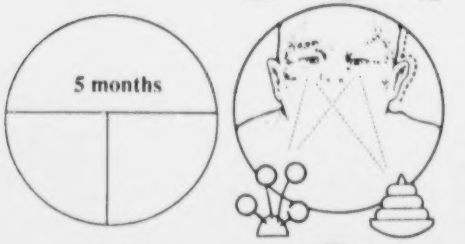
Functional Focal Lengths
Near space: 3 - 12"
Middle space: 1 - 6'
Far space: 6 - 20'
Distant space: 20' - infinity

Shift Gaze: eyes move from one target to another within same focal length or between different focal lengths

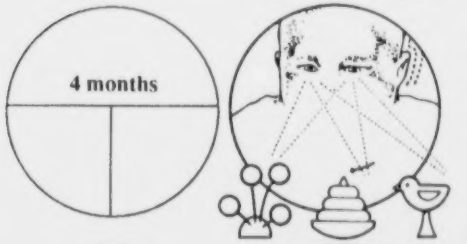
Alternate Glance: between 2 targets
Scanning: between 3 or more targets



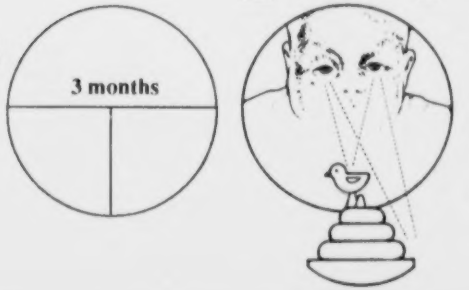
Scans 3 or more targets within **all focal lengths** quickly and accurately
Eyes move independently from **head** to shift gaze
Alternates glance between 2 targets in **same focal length** within **far space** easily
Shifts gaze between targets in **near** and **far space** quickly and accurately
Shifts gaze within and between all focal lengths without **blinking**
Shifts gaze easily during adaptive interaction of **eye/hand/mouth**: regards target, grasps, mouths, withdraws, regards, manipulates, releases, resecures, etc.



Alternates glance between 2 targets in **same focal length** within **middle space** easily
Alternates glance between 2 targets in **same focal length** within **near space** easily
Shifts gaze between targets in **middle** and **far space** accurately
Shifts gaze between targets in **near** and **middle space** accurately
Scans 3 or more targets in **middle space** quickly but inaccurately
Eyes begin to move independently from **head** to shift gaze
Shifts gaze between **near** and **far space** (releases fixation) during adaptive interaction of **eye/hand/mouth** (grasping, manipulating, mouthing target)



Conjugate Deviations: eyes consistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **far space** inaccurately
Scans 3 or more targets in **near space**, overshooting, re-localizing
Tenacious fixation interferes with smooth release (**alternate glance**) in **near space**
Shifts gaze between targets in **near** and **middle space** inaccurately
Shifts gaze between targets in **near** and **far space** with **blinking** and eye-rolling
Shifts gaze from **surroundings** to target in own **hand** after mouthing



Conjugate Deviations: eyes inconsistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **middle space** inaccurately
Begins to shift gaze between targets in near and middle space slowly, with difficulty
Eyes and **head** move together consistently during voluntary gaze shifts
Shifts gaze between own **hand** and target during approach
Alternates glance between target placed on surface and **hand** withdrawn
Shifts gaze consistently without **blinking** between targets in same focal length.

2. d. GAZE SHIFT (VISUAL RELEASE)

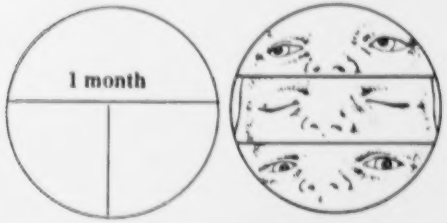
Conjugate Deviations: eyes move together in same direction at same time (yoked)

Components of Gaze Shift (Alternate Glance or Scanning)
1. Release of fixation on target 2. Re-localization on next target 3. Repeat

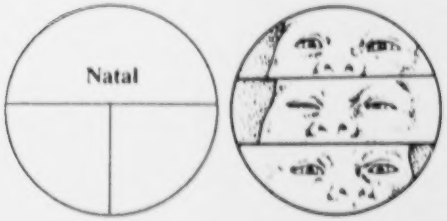
Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction	

Conjugate Deviations: eyes move voluntarily more than involuntarily (randomly)
Conjugate Deviations: eyes move separately during primarily voluntary gaze shifts
Shifts gaze in **same focal length** in **near space**, inaccurately, overshooting target
Shifts gaze from own **hand** to **surroundings** (releases fixation)
Shifts gaze consistently without **blinking** during involuntary gaze shifts
Shifts gaze inconsistently without **blinking** during voluntary gaze shifts (release of focal fixation)



Conjugate Deviations: eyes move separately during beginning voluntary gaze shifts
Conjugate Deviations: eyes move together during primarily involuntary gaze shifts
Eyes and **head** move together inconsistently during beginning voluntary movements
Blinks consistently during release of ambient fixation (stare at surroundings)



Conjugate Deviations: eyes move together during involuntary gaze shifts
Eyes and **head** move together during random movements of both
Blinks inconsistently during release of ambient fixation (stare at surroundings)

Mid Stage (7-8 months)

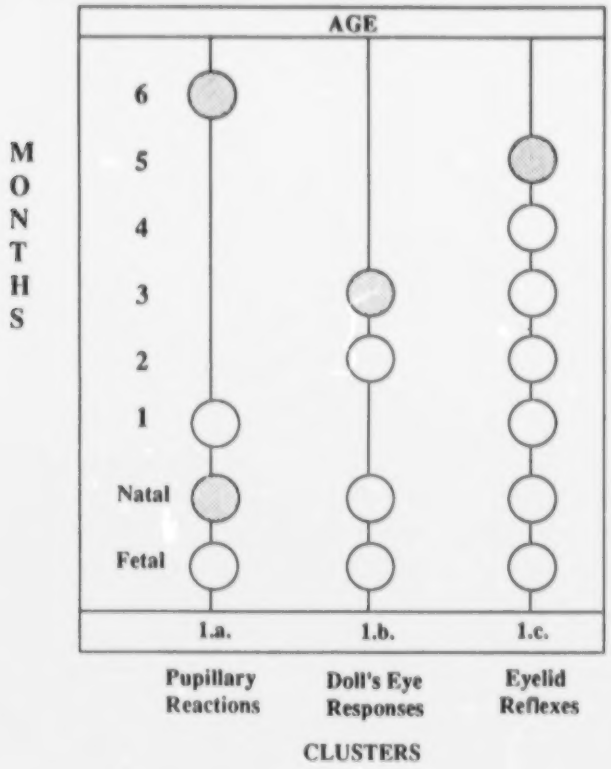
No **eye/hand** interaction during eye movements
Random, sluggish **blinks** during eye movements
Involuntary gaze shifts between **different focal lengths**
Involuntary gaze shifts in **same focal length**

Early Stage (6-7 months)

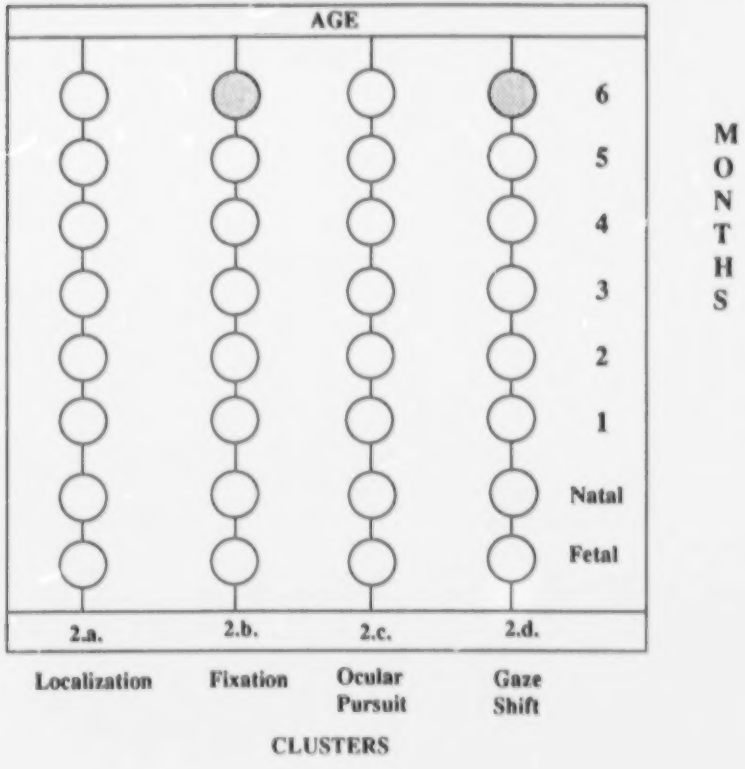
Conjugate Deviations: eyes move co-jointly in all directions during involuntary movements even under closed lids
Eyes move independently from **head** during random movements of both

Score Sheet (Developmental Levels)

Section 1. Primarily Involuntary Visual Patterns (Reflexive)



Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)



Summary

Periodic Blink: _____ per minute
SECTION 1. Primarily Involuntary Visual Patterns (Reflexive) _____ months
SECTION 2. Primarily Voluntary Eye Movements (Cognitively-directed) _____ months

Subject: _____ Examiner: _____ Test Date: _____

Birthdate: _____ Chronological Age: _____ Diagnoses: _____

Erhardt Developmental Vision Assessment (EDVA-S)©

Short Screening Form

By Rhoda P. Erhardt

Contents

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b. Doll's Eye Responses
c. Eyelid Reflexes

SECTION 2. Primarily Voluntary Eye Movements (Cognitively-directed)

a. Localization (Visual Approach)
b. Fixation (Visual Grasp)
c. Ocular Pursuit (Visual Manipulation)
d. Gaze Shift (Visual Release)

Subject: _____ **Examiner:** _____

Birthdate: _____ **Chronological Age:** _____ **Test Date:** _____

Diagnoses: _____

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INSTRUCTIONS

Materials

Appropriate test materials should be selected according to each subject's age, gender, cognitive, cultural, and personal interests, with enough novelty to avoid satiation or habituation. Information regarding developmentally and age-appropriate stimuli will be determined from Clusters 2.a. and 2.b., and may be used for 2.c. and 2.d. At least one identical paired set of stimuli for each category (light, sound, movement, contour/pattern, etc.) should be included as well as test booklet, pencil with eraser, and adjustable eye patch for occlusion of each eye.

Inanimate Visual

- Light sources: penlight, flashlight, lamps, Christmas tree lights (focalized); window areas (diffused)
- Targets which glitter when illuminated: gold or silver jewelry, crumpled foil, Christmas swags, prisms
- Targets with pattern and/or color: black and white stripes and bull's eyes, fluorescents and bright colors (red, orange, yellow)
- Targets with contour: motionless persons, dolls, stuffed animals (3-dimensional); pictures, books, photographs, alphabet letters, and numbers (2-dimensional)
- Tiny targets: edible and non-edible pellets

Inanimate Auditory

- Targets with sound attributes only: bells, music boxes, squeak toys, toy horns, whistles, non-visualized human voice, radio, or tape recorder

Animate Visual

- Targets with internal movement only: puppets (hand, finger, stick), dangling mobiles, pinwheel, mirrors, flutterball, non-vocalizing faces, sequined glove, enclosed glass snow scene
- Moving targets without sound: balloons, soap bubbles, balls, pompoms

Animate Visual and Auditory

- Targets with both sound and movement: rattles, wind-up and battery-operated toys, music boxes, car keys, metronome, vocalizing faces

Administration

Unless videotaped, the test should be administered with the help of an assistant (other professional, paraprofessional, or parent) to share the multiple tasks of presenting stimuli, observing visual responses, and recording scores. Examiners should be alert to the visually distracting effects of strongly patterned or brightly colored clothing.

The test has been designed for subjects of all cognitive levels and chronological ages over six months. Verbal directions may be given but are not required, as each stimulus is presented and responses are observed. Some subjects may be more cooperative if the procedures are explained, e.g., "I'm going to shine this light in your eye"; others may need to be engaged in intermittent conversation to maintain attention.

Subjects who wear prescriptive lenses should remove them for testing of reflexive patterns only.

Testing should be done with both eyes open for all items and, if necessary, with each eye occluded for Clusters 2.b. Fixation (to determine functional stability), and 2.c. Ocular Pursuit (to determine functional mobility). All tracking in 2.c. must be done in arcs of constant focal length to avoid requiring subject to change focus in addition to exerting extraocular muscle control.

Adequate response time should be allowed for subjects with long latency periods due to motoric dysfunction.

Periodic blink should be observed and informally recorded before formal testing to distinguish between the subject's normal blink rate and blinks related to eyelid reflexes, gaze shifts, or generalized visual fatigue after extended testing (see end of fourth page of the short form).

Scoring Procedures

Pattern Components Key:

⊕ Well-integrated normal pattern ⊖ Pattern not present ⊜ Emerging or inconsistent pattern

Section 1. Primarily Involuntary Visual Patterns (Reflexive)

1.a. PUPILLARY REACTIONS

Stimuli: Penlight (**weak** light) and Flashlight (**strong** light) directed into one eye within 12" in dimly lit room

Functional Implications: Tests rapidity of environmental adaptation since light is the first activation of the visual system

Pattern Components	
R	L
Eye	

Direct Light Reflex

- ○○ Pupil constricts quickly to **weak** light directed into eye
- ○○ Pupil dilates quickly when **weak** light is removed from eye
- ○○ Pupil constricts quickly to **strong** light directed into eye
- ○○ Pupil dilates quickly when **strong** light is removed from eye

Pattern Components	
R	L
Eye	

Consensual Light Reflex
(stimulation of one pupil results in equal constriction of both)

- ○○ Pupil constricts quickly and equally to **weak** light directed into **other** eye
- ○○ Pupil dilates quickly and equally when **weak** light is removed from **other** eye
- ○○ Pupil constricts quickly and equally to **strong** light directed into **other** eye
- ○○ Pupil dilates quickly and equally when **strong** light is removed from **other** eye

1.b. DOLL'S EYE RESPONSES

Stimuli: Passive movement of head against body

Functional Implications: Prepares for voluntary separation of eyes from head
Integrated when eyes and head move together voluntarily

Pattern Components	
R	L
Direction	

Head Rotation

- ○○ Eyes move in same direction as head **rotation:** Integrated

Eyes should not be fixating on a target during the rapid passive head-turning

Pattern Components	
R	L
Eye	

Head Flexion/Extension

- ○○ Eyes move in same direction as head **flexion:** Integrated
- ○○ Eyes move in same direction as head **extension:** Integrated

1.c. EYELID REFLEXES

	Stimuli	Functional Implications
Defensive Blink to Threat	Rapid approach and removal of visualized target (Small: spread fingers; Large: test booklet)	Protects eyes from tactile assault
McCarthy's Reflex	Light non-visualized tap above one eyebrow (supraorbital area)	Activates unilateral eyelid function
Naso-Palpebral Reflex	Light non-visualized tap on bridge of nose	Activates bilateral eyelid function
Eye-Neck Reflex	Bright light in eyes, head unsupported (flashlight)	Primitive survival reaction
Visuo-Palpebral Reflex	Bright light in eyes (flashlight)	Protects eye from excessive light
Cochleo-Palpebral Reflex	Sharp noise (hand clap)	Protects eye from certain non-visual stimuli

Pattern Components
R | L
Field

Defensive Blink to Threat

○○ Immediate and consistent to **small** target in **peripheral** field

○ Immediate and consistent to **small** target in **central** field

○○ Immediate and consistent to **large** target in **peripheral** field

○ Immediate and consistent to **large** target in **central** field

○○ **Cochleo-Palpebral Reflex:** blinking of both eyes without global responses

Pattern Components
R | L
Eye

○○ Consistent and equal **eyelid opening** in normal illumination (both fully open)

○○ **Eye-Neck Reflex:** integrated in full-term infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backwards)

○○ **McCarthy's Reflex:** integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap

○○ **Naso-Palpebral Reflex:** integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap

○○ **Visuo-Palpebral Reflex:** tight eyelid closure

Periodic Blink: _____ per minute

Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)

2.a. LOCALIZATION (VISUAL APPROACH)

Testing localization of penlight into peripheral field from each side and above: Examiner stands behind subject who is fixating on another target at central fixation point. To test from below: Subject reclines as target is brought upward from feet.

Pattern Components	
R	L
Direction	

Turns eyes directly to non-visualized sound source above or below ear
Eyes move independently from stabilized **head** to localize target
Eyes and **head** move together consistently to localize target
Localizes non-vocalizing **face** in far space
Smiles at own **face** in mirror spontaneously or when tapped
Localizes large **moving** target in **far** space
Localizes large target by **contour/pattern** in **far** space
From side
From above
From below
> Localizes **penlight** moving slowly into peripheral field in an arc 12" away at 90° from central fixation point (tested in subdued light)
Adjusts **body** position to localize target more easily
Eyes localize, then **hand** approaches and contacts tiny target
Eyes and **hand** pursue lost small target outside visual field
Eyes localize and **hand** grasps small target in near space
Eyes regard own **hand** spontaneously
Prompt regard to target presented **centrally** (in body midline)

Stimuli
Light Sound Faces Contour Movement

Target Size
Large: bigger than examiner's hand Small: size of hand or smaller Tiny: pellet size

2.b. FIXATION (VISUAL GRASP)

Fixation Criteria (Global responses mature to visual only)	
Global Eyes and mouth open, increased or decreased respiration, muscle tone, or body activity	**Visual** Pupils constricted, eyes round rather than oval, upper eyelids tensed and raised, eyes relatively immobile

Focal Lengths
Near space: 3"-12" Middle space: 1'-6' Far space: 6'-20' Distant space: 20'-infinity

Modes of Visual Processing
Ambient: passive stare, with awareness of surroundings Focal: active focus on target, excluding surroundings

Pattern Components	
R	L
Field (Both Eyes)	

Pattern Components	
R	L
Eye (Other Occluded)	

Efficient **ambient** inspection of surroundings in middle and far space
Intense **focal** fixation with visual responses, global suppressed
Eyes fixate on tiny target while **hand** approaches and contacts
Eyes maintain fixation on small target in **hand**
Consistent **binocular fixation**
Fixates at **focal lengths:** 3"-20'
Inspects own **face** in mirror intently
Maintains fixation on non-vocalizing **face** for 10 seconds
Maintains fixation on stationary target in competition with **moving** one
Direct, discriminate **focal** fixation on target in midline
Fixates longer on black and white bull's eye **pattern** than stripes

2.c. OCULAR PURSUIT (VISUAL MANIPULATION)

Tracking Movements	Vergence Movements
Eyes remain on target during horizontal, vertical, circular, and diagonal movements	Eyes remain on target during convergence and divergence in all focal lengths

Pattern Components	
R	L
Direction (Both Eyes)	

Pattern Components	
R	L
Eye (Other Occluded)	

Tracks target **horizontally 180°** smoothly at all speeds, **focal length 3"-infinity**
Tracks to **circular** direction smoothly at all speeds and focal lengths
Tracks **vertically upward** smoothly at all speeds and focal lengths
Tracks **vertically downward** smoothly at all speeds and focal lengths
Smooth **convergence** from far to near space
Smooth **divergence** from near to far space
Eyes move independently from **head** to extreme right/left fields while tracking
Compensatory Eye Movements: eyes remain on stationary target consistently during rapid and extensive voluntary head movements

2.d. GAZE SHIFT (VISUAL RELEASE)

Pattern Components	
R	L
Direction	

Shift Gaze: eyes move from one target to another within same focal length or between different focal lengths

Alternate Glance: between 2 targets
Scanning: between 3 or more targets

Functional Focal Lengths
Near space: 3"-12"
Middle space: 1'-6'
Far space: 6'-20'
Distant space: 20'-infinity

Scans 3 or more targets within **all focal lengths** quickly and accurately
Alternates glance between 2 targets in **same focal length** within **far space** easily
Alternates glance between 2 targets in **same focal length** within **middle space** easily
Alternates glance between 2 targets in **same focal length** within **near space** easily
Shifts gaze between targets in **near** and **far space** quickly and accurately
Shifts gaze between targets in **middle** and **far space** accurately
Shifts gaze between targets in **near** and **middle space** accurately
Conjugate Deviations: eyes consistently move together voluntarily
Shifts gaze within and between all focal lengths without **blinking**
Eyes move independently from **head** to shift gaze
Shifts gaze easily during adaptive interaction of **eye/hand/mouth:** regards target, grasps, mouths, withdraws, regards, manipulates, releases, resecures, etc.

SUMMARY

Score

Cluster

1.a. Pupillary Reactions
1.b. Doll's Eye Responses
1.c. Eyelid Reflexes
2.a. Localization
2.b. Fixation
2.c. Ocular Pursuit
2.d. Gaze Shift

Key: (+) All Scores (+)
(-) All Scores (-)
(±) Mixture of (+), (-), and/or (±)

This EDVA-S (short screening form) contains all test items in the EDVA (long form) that represent norms acquired by six months of age. Clusters with imperfect scores should be retested with the EDVA.

Chapter Six
Models for Assessment

The eye is the first circle;
the horizon which it forms is the second;
and throughout nature this primary figure is repeated without end.
(Gesell, Ilg, and Bullis 1949, frontispiece)

Characteristics of a Model

The major importance of models is that they provide an operating framework, a structure and form, that leads to an orderly way of thinking and doing things. Some models, however, may be self-limiting. One that emphasizes the sensory aspects of vision, for example, may cause problems for the motor concepts or vice versa. Or a model that stresses the innateness or genetic characteristics of vision may not accept data indicating the importance of the learned aspects, and again, vice versa. Similar problems may exist with the dichotomies of optical/neurological or functional/developmental models. Another concern relates to the rapid expansion of scientific knowledge, requiring certain ideas to be continually revised or even deleted. Good working models, therefore, must be flexible and adjustable and should contain elements of useful knowledge that, like the spokes of a wheel, converge toward a hub of ultimate truth (Forrest 1978).

Developmental Visual Sequence Clusters

The Erhardt Developmental Vision Assessment (EDVA), a comprehensive sequence of visual pattern components compiled from developmental norms in the literature, had been organized and refined through research methods already described: historical documentation (case study data), observational methods (videotapes), and experimental research (informal field studies and an interrater reliability study). Illustrations of selected pattern components in each cluster of the EDVA provide a visual representation of development from the fetal or prenatal level to six months in a vertical orientation. The EDVA summary page provides a horizontal orientation for correlation of pattern components at each developmental level within all clusters (pupillary reactions, doll's eye responses, eyelid reflexes, localization, fixation, ocular pursuit, and gaze shift). Figure 6-1 presents a visual representation of the summary page of the EDVA.

A Theoretical Model of Inappropriate Patterns

Analysis of the model developmental visual sequence clusters (fig. 6-1) reveals, in a vertical direction, the intricate yet logical ways that each developmental pattern prepares for the next sequential pattern as voluntary muscle control increases and reflexive movements decrease. The model also demonstrates horizontally the interdependent relationships between skills in each cluster and developmentally corresponding skills in the other clusters.

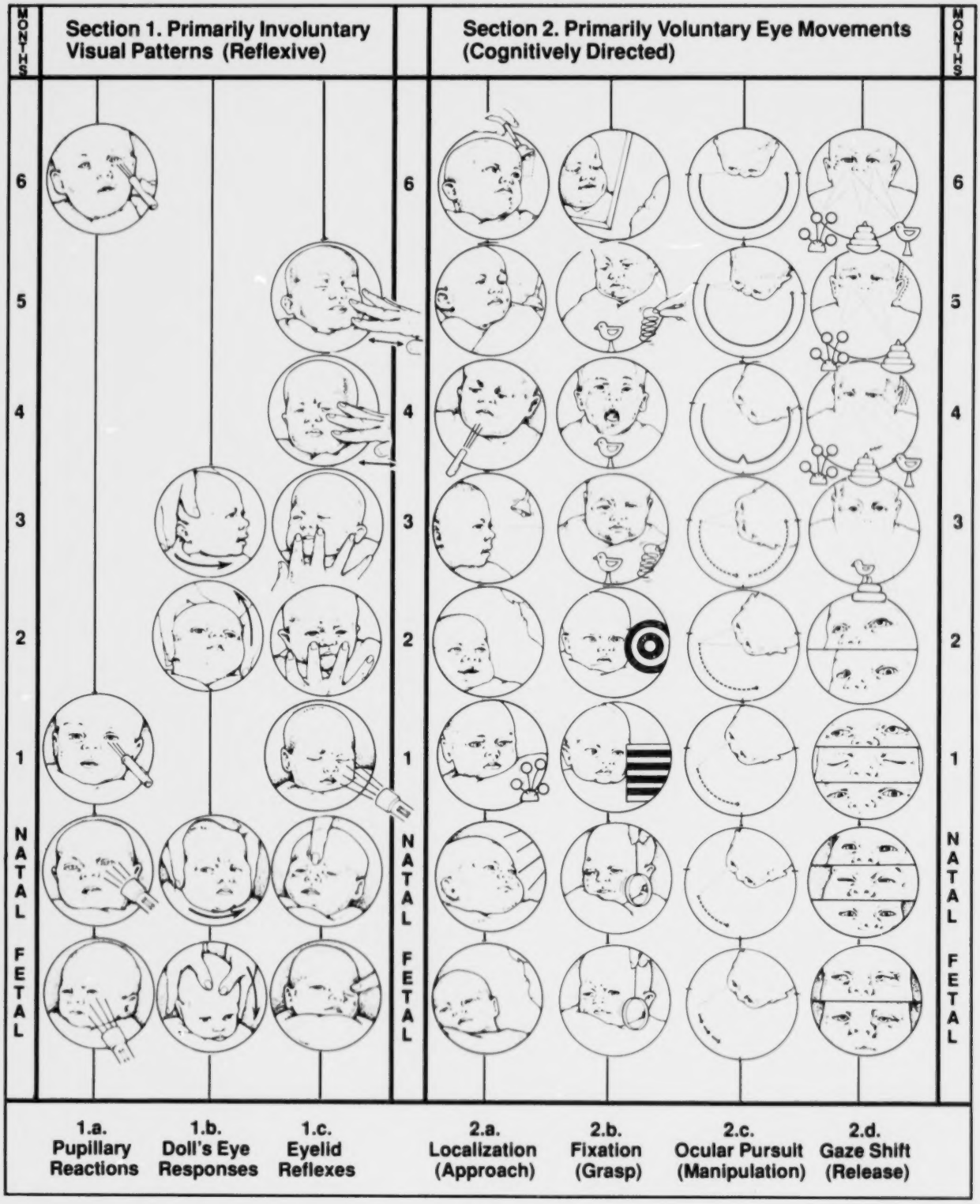


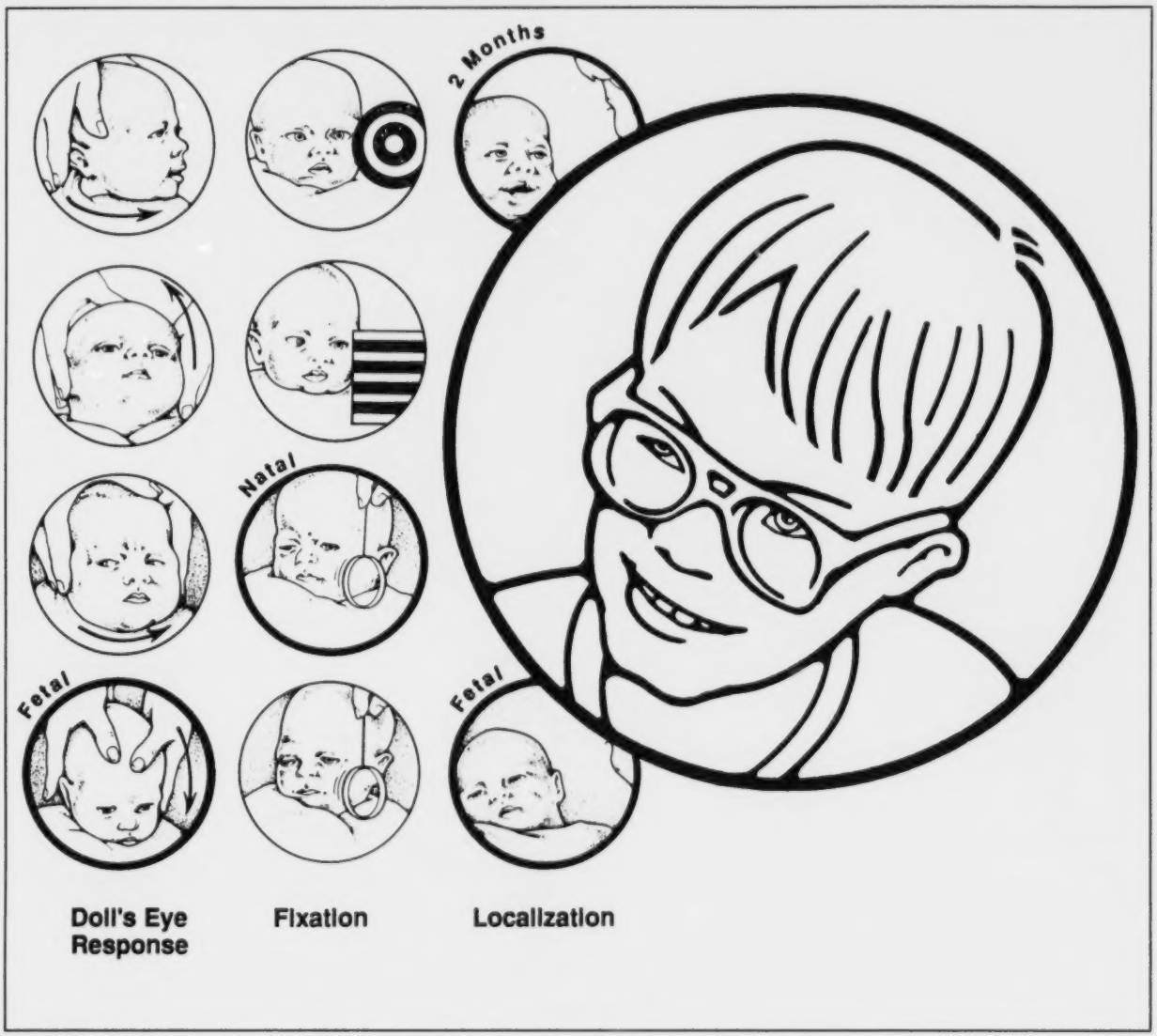
Fig. 6-1

Developmental Visual Sequence Clusters

The value of developmental testing for providing a method of analyzing apparent abnormal patterns can be illustrated by figure 6-2.

Joseph's posture (eyes, head, and trunk alignment) is typical of many older children with cerebral palsy. His shoulders are elevated and asymmetrical, left higher than the right. His neck shows cervical flexion and capital extension, with his head rotated to the right and tilted laterally toward the left. He fixates with his left eye only, while his right deviates outward. The right eye is smaller than the left. Some of his postural compensations are related to physiological factors such as hemianopsia, optic nerve damage, and cataracts, but many visual components of his posture can be identified in the illustrated sequences of normal development.

In the sequence of doll's eye response, the normal infant at the *fetal* level shows eye/head relationships during neck flexion that are similar to those demonstrated by Joseph. Fixation at the *natal* level, in the normal infant as well as Joseph, shows unequal eyelid opening, even in subdued light, and monocular fixation with the inactive eye deviating nasally (toward the nose) or temporally (toward the ear), with the head rotated to bring the target into the visual field. Like the eye of the *fetal* infant, which has



Source: Erhardt 1982

Fig. 6-2

Use of a Theory of Inappropriate Patterns Relating to Developmental Visual Dysfunction

no focal vision, Joseph's right eye does not localize to faces. His left eye localizes to nonvocalizing as well as vocalizing faces, as in the *two-month-old*. Joseph's elevated shoulders and general postural asymmetry are typical postures below the three-month level in normal infants.

This theoretical model of inappropriate patterns can serve as a link, or bridge, between assessment and intervention.

Assessment of the Environment

The central purpose of childhood is to develop competence in a series of tasks that prepare the individual for a happy, healthy, and productive life. Assorted behaviors serve different functions at various stages in each person's life history. Competence implies action, that is, operating on the environment to bring about particular desired ends as well as adapting to the demands of the environment. The basic attributes of tasks involved in developing competence include the following:

1. Selecting features from the total environment that provide relevant information for planning a specific course of action (requires visual attention, discrimination, and filtering)
2. Initiating a sequence of actions to achieve the intended objectives (requires orchestration of motor and cognitive skills)
3. Utilizing what has been learned from successes and failures to formulate new plans (requires repeated adjustments to changes in self and the environment) (Connolly 1974).

Prioritizing Needs in Terms of Function

For many children, especially those with severe handicaps, more deficits are identified than can possibly be remediated. A process is needed for establishing priorities among possible goals and objectives. Determining what a student needs to learn is best done not by elaborating on what he or she *cannot* do, but by asking a set of additional questions. What do the parents want their young child to learn? What would increase the child's contribution to family life as well as his or her participation in integrated school and community settings? What are the choices of the older student from typical activities of nonhandicapped age peers? What are some of the demands and opportunities in the local community? The answers to these questions give valuable information about what the student's priorities are and need to be. In other words, assessing the student's environment is as important as assessing his or her abilities. Thus, decisions must be based on a definition of performance that considers individual values, program plans must include clear statements of what activities mean in terms of function, and assessment must be done within the context of life management. Intervention depends on assessment data, but values, priorities, and future goals must be part of the assessment process (Wilcox 1986).

Frames of Reference

The relationship of theories, frames of reference, and activities must be understood by professional teams planning and implementing intervention programs. The purpose of theories, which consist of concepts, definitions, and statements, is to describe, explain, and predict. Frames of reference are usually derived from theoretical constructs, but additionally include guides for action. Statements of theories may include views of function and dysfunction, intervention strategies focused on facilitating change, and sometimes the activities consistent with those strategies. Activities are tasks, techniques, or processes designed to assist the student in reaching goals. If an activity is meaningful to the student and will help him or her become more functional, it can be considered "purposeful," a key word in the philosophical base of occupational therapy. To be therapeutic, however, an activity must have a frame of reference and theoretical base. Several different frames of reference may be used simultaneously or sequentially for the same or different problem. Most importantly, evaluation and intervention should *both* be in the same mode or approach (Holm 1988).

Traditional models focused on identification of strengths (function) and weaknesses (dysfunction). Goals and strategies were then designed to remediate the weaknesses, skills not currently within the student's abilities. As parents and teachers became increasingly frustrated with very small gains achieved by children with severe and multiple handicaps, a prevention-intervention focus offered a different, more positive perspective for the children, families, and professionals. The approach

recognizes that some things such as certain physical or visual impairments simply cannot be fixed through medical, educational, or therapeutic interventions. The brain damage is static, and in some respects, unalterable. The prevention-intervention approach can minimize the impact of primary impairments in creating secondary handicaps by planning and teaching alternative methods of achieving functional skills within different frames of reference (Campbell and Wilcox 1986; Feuerstein 1980).

The functional approach is consistent with both the biomechanical and rehabilitation frames of reference. If evaluation identifies visual and motor impairments that are static, that is, not amenable to significant change through developmental continuums, intervention plans need to consider *functionally appropriate adaptations*. The developmental frame of reference is consistent with the occupational frame of reference, which considers the child's occupational role to be that of a learner (through play, structured school experiences, and increasing independence in self-help skills). This frame of reference will address those impairments that are still in a state of dynamic process and is useful for planning *developmentally targeted interventions* (Holm 1988). Table 6 presents a comparison of functional and developmental frames of reference, with corresponding states of function/dysfunction identified by evaluation and the focus of intervention/activities for each.

Data Collection

The models for assessment and analysis of dysfunction (figs. 6-1, 6-2) provide important information based on a developmental approach. However, developmental information is only a small part of what is needed to assess total visual function. A great variety as well as quantity of additional data must be collected from many different sources in order to create intervention plans that consider the impact of vision on almost every aspect of life. Figure 6-3 describes how to expand this data base to include medical and educational information, assessment of the environment, and determination of functional priorities. It divides the process into assessment of the child (medical, educational, and developmental data) and assessment of the environment (functional data), and includes a list of team members who are sources of this information. This model facilitates the synthesizing process and prepares for use of the model for management of visual-motor dysfunction, which will be presented in the next chapter.

TABLE 6
Two Frames of Reference: Guides for Action

Theoretical Construct	Functional (consistent with biomechanical or rehabilitation)	Developmental (consistent with occupational)
State of Function	Demonstrates adequate functional skills or appropriate compensations for limitations	Demonstrates skills and subskills in a predictable and sequential manner, spontaneously exploring meaningful and valued interests within self-perceived roles
State of Dysfunction	Demonstrates inadequate functional skills and inappropriate compensations for limitations	Demonstrates skills and subskills below age and stage; developmental gaps interfere with efficient pursuit of intrinsically motivated goals for role fulfillment
Focus of Intervention	Identify discrepancy between skill requirements and present functions, especially those that will never be performed independently; determine and implement best methods for adaptation *to* and *of* the environment	Identify subskills which are not age/stage consistent; determine internal/external expectations of skills desired for role fulfillment; facilitate acquisition of missing subskills, beginning at present developmental level and moving sequentially higher on the continuum
Activities	Determine best methods for task performance and design functionally appropriate adaptations of positioning, materials, and equipment	Structure purposeful and successful activities to facilitate developmentally targeted interventions, based on task analysis, personal interests, and role requirements

Source: Holm 1988

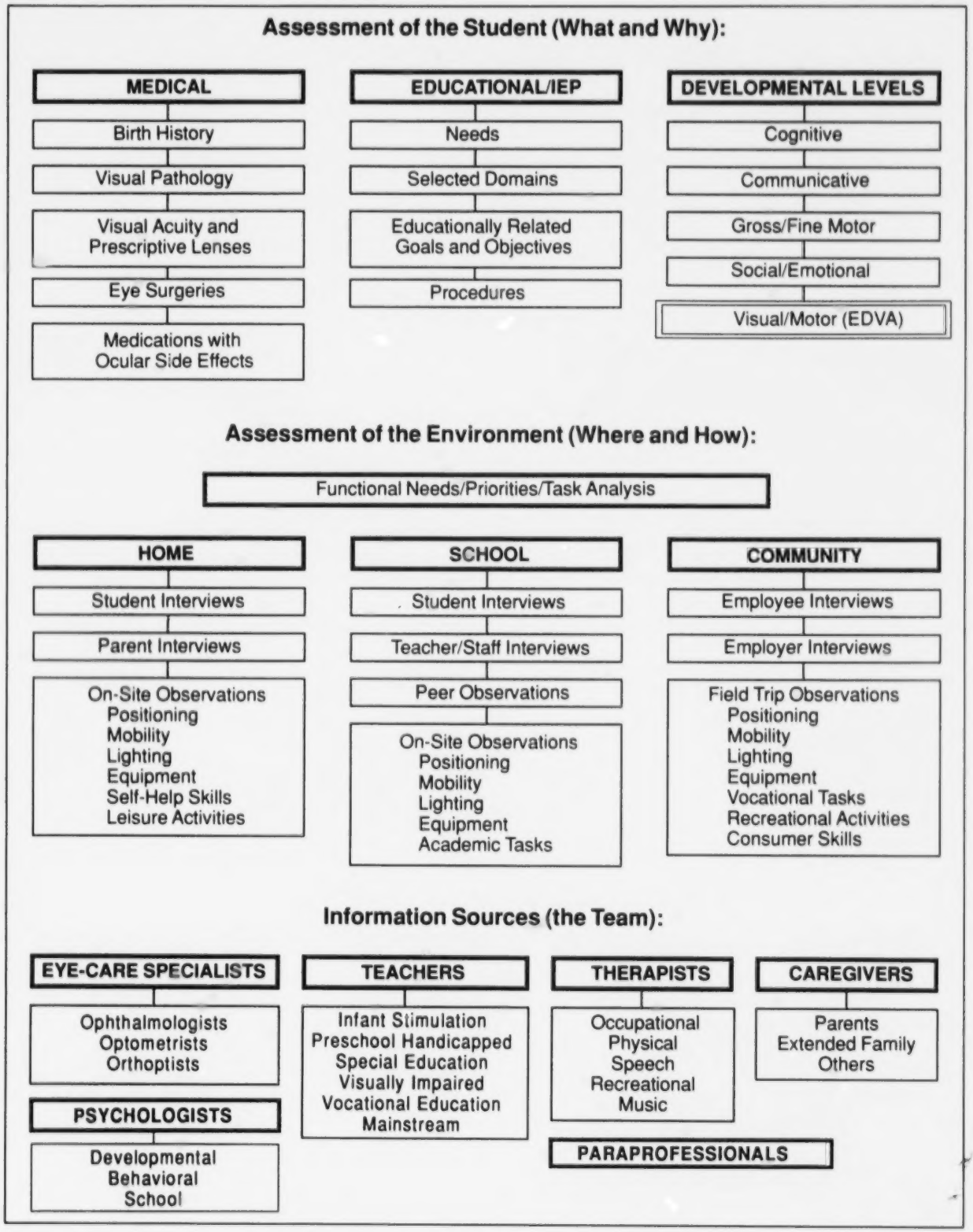


Fig. 6-3

A Model for Visual-Motor Data Collection

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PART THREE:

From Assessment to Management

Chapter Seven
A Model for Management of Visual-Motor Dysfunction

No one of the major fields of behavior—
motor, adaptive, language, and personal-social—
is normally devoid of visual content or visual controls.
So interfused are vision and action systems that the two must be regarded as inseparable.
(Gesell, Ilg, and Bullis 1949, 14)

The Inseparability of Assessment and Intervention

Children with moderate or severe multiple handicaps have received more collaborative attention from a variety of professionals since the passage and implementation in 1978 of Public Law 94-142, the Education of the Handicapped Act, which has required professionals to work together to develop Individualized Education Plans (IEPs). The successful decision-making process of evaluating skills, analyzing the functional importance of these skills, and selecting intervention procedures depends on the ability of these professionals to skillfully integrate all of the gathered and shared information (Evans and Meyer 1985).

Organizations such as The Association for Persons with Severe Handicaps (TASH), whose advocacy efforts contributed to the passage of P. L. 94-142 and P. L. 99-457, the Education of the Handicapped Amendments of 1986, continue to work toward integration of persons with handicaps into community as well as educational settings. A position statement of the TASH Related Services Subcommittee recommends assessment in natural settings in order to provide intervention strategies and adaptations in those same settings (TASH 1987).

If educational objectives are to be age appropriate and designed for maximum participation in integrated environments, the basic values underlying normalization must be reflected in assessment approaches and procedures and the critical role of families needs to be recognized (Horner, Meyer, and Frederick 1986).

A Transactional Approach

The child is considered within the social context of the family, school, and community, not in isolation, as a goal-oriented being who influences the world around him or her as much as he or she is influenced by it. A transactional approach views development and behavior as a process of transactions between the child and the environment, determined and modifiable by experiences. The child is characterized as a unique organism continuously evolving from organism/environment transactions, driven to action, and seeking stimulation. This approach places emphasis on natural behavior settings, the effects of environment on individuals, and ways of modifying the system with awareness of the effect on the individual.

Ecological assessment can identify the contexts in which a child functions and assist in determining

what environmental changes can contribute to more appropriate adaptive behaviors. Shifting the assessment focus to the natural context also recognizes the role of the surroundings in the problem and the environmental factors influencing the child. The emphasis can be on altering the environment to better accommodate the child rather than changing the child to adapt to the demands of the setting. Remembering that children are stimulus-seeking beings can help generate the best blend of the child's needs and the task characteristics (the task-learner characteristic model). Within this model the learner is regarded as an information-processing entity, possessing capabilities for reception, stimulus management, storage, and retrieval.

Through discussion of assessment and intervention in terms of daily life experience, the team of professionals and family members can move away from the model of pathology and deviation to normality and everyday problems and solutions (Buktenica 1976).

A Prevention-Intervention Approach

Focus on the individual within the context of where he or she lives is especially critical for the prevention-intervention approach. Infants and children with physical and visual impairments are essentially deprived of the environmental experiences needed to learn thinking and problem-solving skills and the chance to communicate easily with others and gain social skills. Children with cerebral palsy can be prevented from developing many abnormal movement patterns, and other secondary handicaps can be reduced or prevented if compensatory and alternative methods are used to provide functional learning (Feuerstein 1980; Campbell and Wilcox 1986).

Clinical and research efforts may be based on either a deficit model or a risk model. The deficit model assumes that an individual who has experienced fundamental damage to the neurophysiological system at birth will have compromised self-organizing abilities. Ongoing difficulties are always attributed to that single event, and future interventions are considered extremely self-limiting. This model has been used to justify giving up on handicapped children and their families. The risk model recognizes that the initial event has jeopardized the developmental process but assumes that organismic and environmental forces can contribute to positive outcomes. This dynamic, transactional model is effective because it considers a process resulting from both constitutional and environmental factors (Weston et al. 1989).

Choosing Frames of Reference

Professionals who have been trained to intervene solely by remediating identified deficits may have difficulty with other frames of reference.

As stated in the previous chapter, assessment based on a specific theoretical frame of reference leads logically into intervention in that same mode or approach. However, several frames of reference may be used simultaneously or sequentially and may change over time for a variety of reasons. From the student's perspective, the choice depends on age, specific performance deficits, and personal preferences. Developmental approaches are usually more appropriate for younger children and bow to more functional emphasis as the years pass. However, current developmental approaches, such as neurodevelopmental treatment, stress the need to build in function during or immediately following therapeutic activities. Agency philosophies may dictate intervention approaches because of funding, personnel, and geographical patterns affecting service delivery modes. Finally, each professional's choices are influenced by previous experiences, body of knowledge, special skills, and certification (Holm 1988; Anderson, Hinojosa, and Strauch 1987).

Evolvement of the Model from Profession-Oriented Academic Domains to Person-Oriented Functional Domains

Team members in multidisciplinary and interdisciplinary models typically conduct their own assessments and treatments in isolation, with communication varying from very little to a great deal. The recent evolution of the transdisciplinary model allows professionals to conduct their respective assessments and releases treatment to one or two facilitators, with ongoing reciprocal and beneficial communication (McCormick and Goldman 1979).

Educational programs for children whose multiple handicaps include significant cortical visual problems have become increasingly sensitive to the implications of posture and movement on visual function and vice versa (Brown, Schuerman, and Crowner 1976; DuBose 1976; Efron and DuBoff 1975;

Fieber and Robinson 1974; Fraiberg 1971; Gates 1985; Jose, Smith, and Shane 1980; Corn 1985).

Developmental progress of normal children is known to be achieved through the complex interaction of four pathways of development: gross-motor skills, hearing and language, social skills and behavior, and vision and eye-hand coordination. Neurological disorders in any of these areas may affect not only the pattern and rate of development in the areas of occurrence but also in each of the other areas. Manipulation and exploration, closely linked with gross-motor activity and development of body image, are essential experiences of the sensorimotor period of human intelligence stages. The child's growth and development, particularly his or her body image, are normally dependent on the synthesis of vision, hearing, touch, and proprioception, of which vision is a major modality (Egan 1979).

Present level of function statements have contained collections of assessments by various professionals leading to goals and objectives that present programs fragmented into developmental areas. Services are traditionally implemented by the respective professionals: cognition (teachers), communication (speech pathologists), gross motor (physical therapists), and fine motor (occupational therapists).

Also fragmented is research describing the visual defects associated with cerebral palsy, including motility problems, nystagmus, and attending skills, as well as refractive errors and optic atrophy (Harley and Altmeyer 1982). The traditional educational view of visual skills as primarily a manifestation of cognition ignores the important motor components of visual development and function. Thus, teachers of the visually impaired, armed with the physician's reports and their own educational assessments, tend to follow the more multidisciplinary or interdisciplinary models, whether functioning as consultants or working directly with each child.

A strategy for incorporating visual procedures into a variety of educational domains was developed by the author and illustrated in a published case study of a 19-year-old male with multiple handicaps (Erhardt 1987). This first model for visual function in home, school, and community environments was used within curricular domains of cognition, communication, self-help, vocational, fine-motor, and gross-motor areas (fig. 7-1). A primary visual component was selected from each section of the Erhardt Developmental Vision Assessment (1986 version) and linked to a functional goal. Procedures were then devised for (1) one-to-one activities that would gain optimal visual function in a quiet area without sound or movement distractions, and (2) environmental reinforcement through group activities that would enable the student to generalize the acquired visual skills despite normal noise levels and movement distractions. Those procedures were also matched to IEP objectives in each academic domain. By matching visual activities to the goal statements and to each behavioral objective, visual components were integrated into procedures in all curricular domains. The model was adaptable to children of different ages and levels of function.

A New Model for Management of Visual-Motor Dysfunction

The first model for visual function in home, school, and community environments gradually evolved into the present model for management of visual-motor dysfunction as educational approaches moved from profession-oriented academic domains to person-oriented functional domains (fig. 7-2). The grassroots movement in educational systems throughout the United States was led by dedicated leaders and pioneers in higher education and advocacy organizations. Individuals were being assessed and intervention planned in terms of life functions: domestic domain, leisure domain, vocational domain, and community domain. Goals and objectives could easily be written for the traditional skill areas of gross-motor, fine-motor, self-help, cognition, and communication within these new functional/environmental domains. However, instead of specific objectives "owned" by certain professionals, for example, gross-motor (physical therapist), fine-motor (occupational therapist), cognitive (teacher), communicative (speech therapist), the new domains demanded that all team members help write, be aware of, and also be responsible for all objectives and thus the student as a whole, not fragmented, person.

For example, the occupational therapist and teacher may be primarily involved in a cooking objective within the *domestic* domain (fine-motor and self-help), but the speech therapist's contributions are essential also for the language requirements of the recipe. The *leisure* domain may involve the physical therapist and adapted physical education teacher for sport activities (gross-motor), as well as the

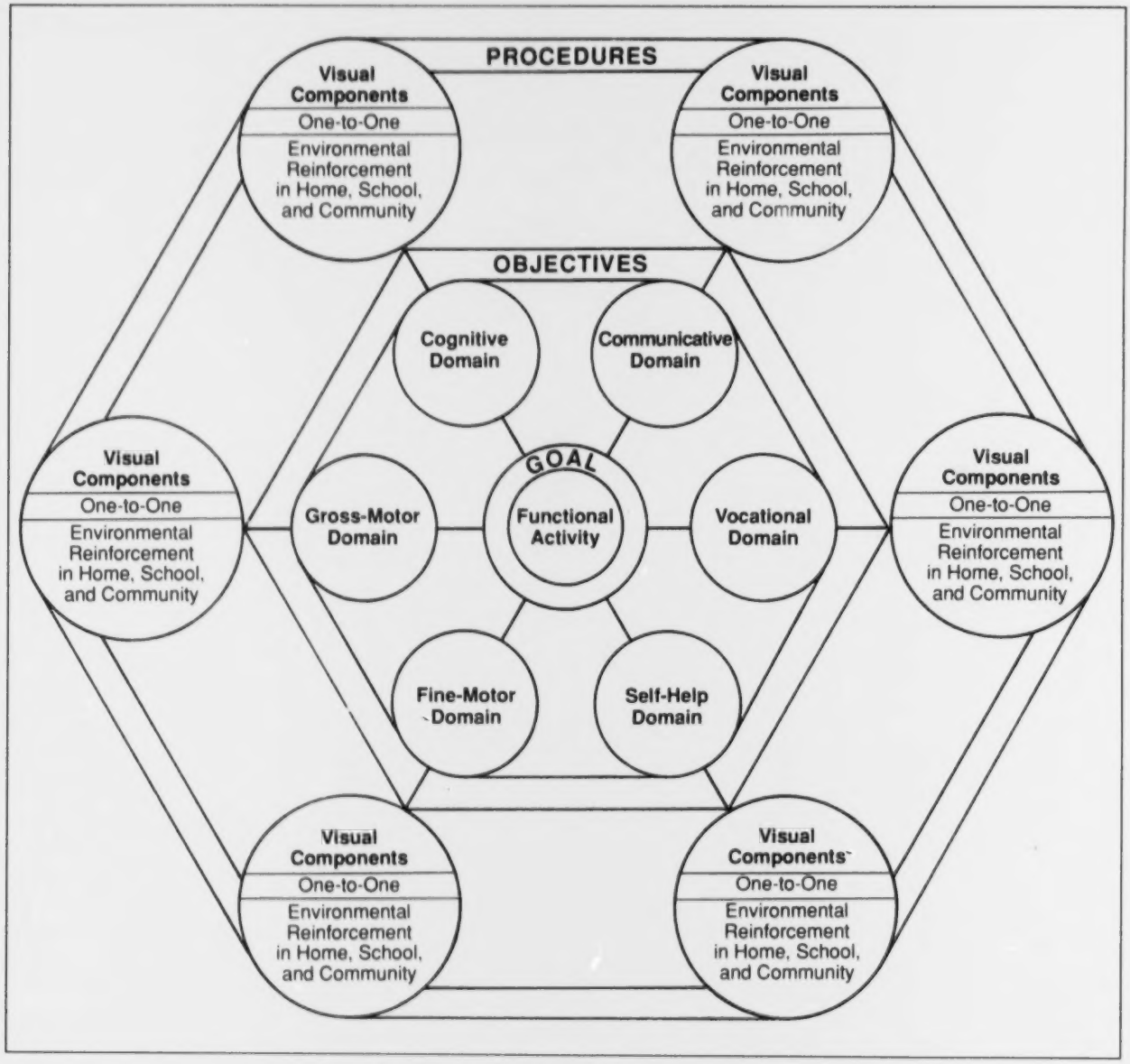

Fig. 7-1

A Model for Visual Function in Home, School, and Community Environments

occupational therapist, teacher, and speech therapist for board games (fine motor, cognitive, and communication). Becoming part of the *community* requires the physical therapist's input for teaching mobility skills or securing powered equipment, but the speech therapist and teacher will need to structure learning experiences for the social and communicative aspects of community integration. The *vocational* domain often requires the entire team's expertise to help the student achieve the maximal potential for independence. School aides as well as family members can also participate in procedures at varying levels in all these environmental domains.

The new model for management of visual-motor dysfunction responds also to a recognition of the different frames of reference and the need to choose each at appropriate times for individual children. Finally, the new model allows the team to move from multidisciplinary and interdisciplinary approaches to the transdisciplinary process, which requires professionals to experience role-release for the benefit

of the student. Through this transdisciplinary process appropriate intervention activities can be integrated into the child's total environment as visual activities are linked to functional goals and behavioral objectives. Functionally appropriate adaptations are recommended for static visual and postural conditions that are due to irreversible pathology or physiological structural limitations. Developmentally targeted interventions are recommended when potential is seen for dynamic process and change. The model still allows a choice of domains for systems that prefer the traditional domains to the environmental or wish to select still other ones.

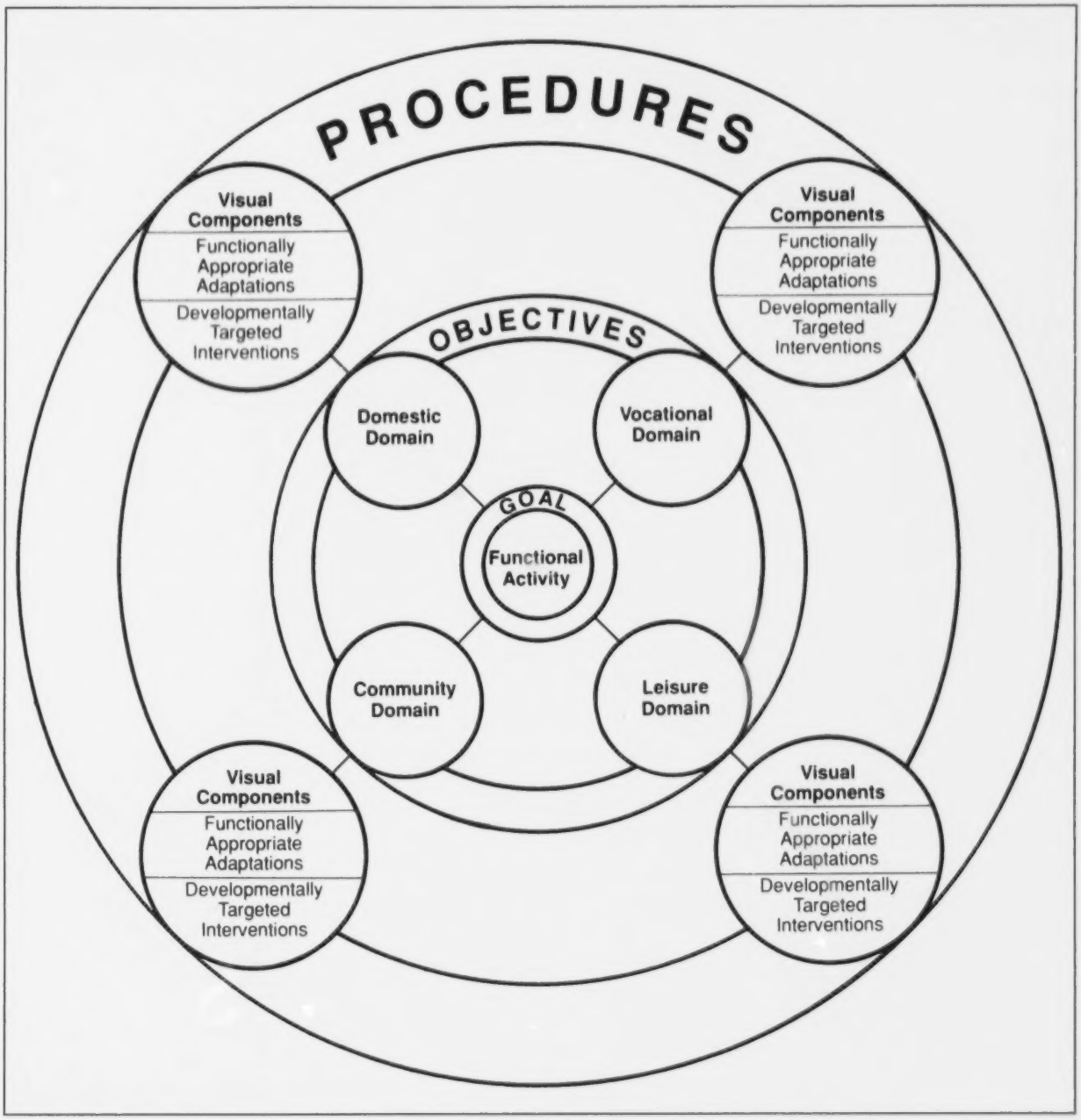

Fig. 7-2

Developmental Visual Dysfunction: A Model for Management

The Visual-Motor Management Process

Once the assessment process has been completed using the model for visual-motor data collection (fig. 6-3), the large quantity and diversity of information must be synthesized and organized as the team develops the individualized intervention plan. The total management process involves the following sequential steps, listed in Table 7: (1) collecting data, (2) selecting priorities within domains, (3) analyzing visual components of functional tasks, (4) matching visual skills with each domain, (5) determining whether visual deficits are dynamic or static, and (6) planning developmentally targeted interventions for dynamic deficits and functionally appropriate adaptations for static conditions.

TABLE 7
The Visual-Motor Management Process

Process	Sources of Information	Model
1. Collecting data	Child's medical, educational, developmental, and functional assessments and records	Model for visual-motor data collection
2. Selecting priorities within domains	Child's IEP team, including child and parents	
3. Analyzing visual components of functional tasks	Activities of daily living in child's home, school, and community	
4. Matching visual skills with each domain	Child's assessments and IEP	Model for management of visual-motor dysfunction
5. Determining whether visual deficits are dynamic or static	Child's assessments and medical records	
6. Planning developmentally targeted interventions for dynamic deficits and functionally appropriate adaptations for static conditions	Child's IEP and the professionals' clinical judgment and creativity	

Models for Writing Assessment Reports

The importance of written evaluations cannot be overemphasized. They serve as the vehicles of communication to all those who are involved in therapeutic intervention (Sattler 1974). All team members, professionals from the medical or educational fields as well as lay persons who are family or friends, should be able to understand language free from technical jargon. Medical and educational terms may be used when appropriate but should be clearly defined and explained (Gilfoyle 1979).

Formats of reports vary greatly according to the type of evaluation, needs of the facility, and individual writing styles. Developmental evaluation reports, however, generally include the following information:

Identifying information: name of facility, type of assessment, name of child, date of birth, chronological age, diagnoses, name of examiner, and date of report.

Referral source: physician, school, or other referring source, reason for referral, concerns of parents and teachers, pertinent medical and educational history.

General observations: where assessment was conducted, who was present, child's state and attitude.

Findings: results, present level of function, clarifying information, clinical observations, and summary of total performance.

Recommendations: answers to referral questions, suggested community resources, re-evaluation timetable.

Signature: examiner's name and title.

Some reports may also include specific recommended therapeutic activities, either as part of the report or as an addendum (Coley 1978).

A suggested report format for the Erhardt Developmental Vision Assessment is presented in the typical format of a computer word-processing fill-in program. The report can consist of only the evaluation or can include recommendations, either general or very specific. The next three chapters illustrate use of this report format with case study examples.

Date:
To:
Re: (type of evaluation) for (name)

This (age)-(month/year)-old (male/female) with a diagnosis of (diagnosis) was evaluated with the Erhardt Developmental Vision Assessment (EDVA), which measures the motor components of vision, both reflexive visual patterns and voluntary eye movements of localization, fixation, ocular pursuit, and gaze shift. (Name)'s eye muscles, both involuntary and voluntary, have been affected by cerebral palsy, defined as a condition in which damage has occurred to areas of the brain controlling the motor system. The most recent (ophthalmic/optometric) report states (findings).

A brief summary of the results will be presented, including the relationship of specific visual findings to the total motor-action system, and implications for function in the home, school, and community environments. Recommendations for a management program integrated with the individualized educational plan (IEP) will include functionally appropriate adaptations and developmentally targeted interventions.

SECTION 1. Primarily Involuntary Visual Patterns (Reflexive)

1.a. Pupillary Reactions
Clinical observations:
Summary and implications for function:
General goal:
Individualized Management Program
Domain
Goal:
Objective:
Visual Component:
Visual Present Level of Function:
Visual Procedures
Functionally Appropriate Adaptations:
Developmentally Targeted Interventions:

1.b. Doll's Eye Responses
Clinical observations:
Summary and implications for function:
General goal:
Individualized Management Program
Domain
Goal:
Objective:
Visual Component:
Visual Present Level of Function:
Visual Procedures
Functionally Appropriate Adaptations:
Developmentally Targeted Interventions:

1.c. Eyelid Reflexes
Clinical observations:
Summary and implications for function:
General goal:
Individualized Management Program
Domain
Goal:
Objective:
Visual Component:
Visual Present Level of Function:
Visual Procedures
Functionally Appropriate Adaptations:
Developmentally Targeted Interventions:

SECTION 2. Primarily Voluntary Eye Movements (Cognitively Directed)

2.a. Localization
Clinical observations:
Summary and implications for function:
General goal:
Individualized Management Program
Domain
Goal:
Objective:
Visual Component:
Visual Present Level of Function:
Visual Procedures
Functionally Appropriate Adaptations:
Developmentally Targeted Interventions:

2.b. Fixation
Clinical observations:
Summary and implications for function:
General goal:
Individualized Management Program
Domain
Goal:
Objective:
Visual Component:
Visual Present Level of Function:
Visual Procedures
Functionally Appropriate Adaptations:
Developmentally Targeted Interventions:

2.c. Ocular Pursuit
Clinical observations:
Summary and implications for function:
General goal:
Individualized Management Program
Domain
Goal:
Objective:
Visual Component:
Visual Present Level of Function:
Visual Procedures
Functionally Appropriate Adaptations:
Developmentally Targeted Interventions:

2.d. Gaze Shift
Clinical observations:
Summary and implications for function:
General goal:
Individualized Management Program
Domain
Goal:
Objective:
Visual Component:
Visual Present Level of Function:
Visual Procedures
Functionally Appropriate Adaptations:
Developmentally Targeted Interventions:

Summary and Conclusions
General Recommendations

The EDVA, a developmentally referenced evaluation instrument that measures quantitative and qualitative aspects of visual-motor skills in the developmental range of birth to six months, has been used to determine (Name's) integration of visual reflexive patterns as well as (his/her) acquisition of voluntary eye movements. Results indicated (developmental level expressed in months/scatter of skills ranging from/to/gaps in development under the six-month norm). These missing components, foundations for functional visual tasks, can interfere with complex, automatic, efficient eye movements needed for daily life.

Recommendations for an individualized management program have included functionally appropriate adaptations for static visual conditions and developmentally targeted interventions for dynamic visual potentials.

Re-evaluation is recommended in (range) months.

Signature

Format for Presentation of Sample EDVA Protocol Sheets, Assessment Reports, and Individualized Management Programs

The three sample assessments in the next three chapters are presented in a format that links the EDVA protocol sheets with specific reporting and management planning as well as the recommended visual procedures with IEP, IPP, or IFSP goals and objectives. Photographs are added for clarification.

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Chapter Eight
Joseph: Assessment and Management

Date: August 4, 1986

To: Whom It May Concern

Re: Occupational Therapy Evaluation for Joseph Nilles

This 11½-year-old male with a diagnosis of cerebral palsy was evaluated with the Erhardt Developmental Vision Assessment (EDVA), which measures the motor components of vision, both reflexive visual patterns and voluntary eye movements of localization, fixation, ocular pursuit, and gaze shift. Joseph's eye muscles, both involuntary and voluntary, have been affected by cerebral palsy, which is defined as a condition in which damage has occurred to areas of the brain that control the motor system.

The most recent ophthalmology report stated that Joseph's visual acuity is estimated at 20/200 O.S. (left eye) with corrective lenses (high myopia). He uses primarily the left field of the left eye because of a partial right hemianopsia and a large cataract in his right eye, possibly secondary to retinopathy of prematurity. He also demonstrated a right exotropia and microthalmia plus mild lateral nystagmus in the left eye (Barker-Griffith 1986).

The current optometric report determined that the null point for nystagmus was at 6 inches, the focal length for optimal vision for reading. However, Joseph was able to discriminate 1-inch-high letters at 12-inch focal length. The prescription for his lenses was -14.25 O.D. and -13.75 + 1.25 x 086 O.S., indicating astigmatism as well. A three-base out prism (right) and three-base in prism (left) were included to shift the field of vision to the right and minimize the impact of the partial right field cut. The left prism was also rotated to base up and in axis 135 degrees in an effort to reduce Joseph's head tilt to the left (McLaurin 1989).

A brief summary of the results will be presented, including the relationship of specific visual findings to the total motor action system and implications for function in the home, school, and community environments. Recommendations for a management program integrated with Joseph's individualized educational plan (IEP) will include functionally appropriate adaptations and developmentally targeted interventions.

Joseph's present levels of educational performance indicate that he qualifies for special services including a teacher certified in trainable mentally handicapped; a vision consultant; occupational, physical, and speech/language therapy; adaptive physical education; a classroom aide; and mainstream experiences with age-appropriate peers. Joseph's program next year will be based in the trainable mentally handicapped classroom at the junior high school, with selected regular education classes/activities such as music, library, lunch, recess, and special programs.

Section 1. Primarily Involuntary Visual Patterns (Reflexive)

1. a. PUPILLARY REACTIONS

Stimuli: Penlight (weak light) and flashlight (strong light) directed into one eye within 12" in dimly lit room

Functional Implications: Tests rapidity of environmental adaptation since light is the first activation of the visual system

Developmental Levels		Pattern Components		Pattern Components	
Right	Left	R | L		R | L	
		Eye	**Direct Light Reflex**	Eye	**Consensual Light Reflex** (stimulation of one pupil results in equal constriction of both)
6 months			Pupil constricts quickly to **weak** light directed into eye		Pupil constricts quickly and equally to **weak** light directed into **other** eye
			Pupil dilates quickly when **weak** light is removed from eye		Pupil dilates quickly and equally when **weak** light is removed from **other** eye
1 month			Pupil constricts slowly to **weak** light directed into eye		Pupil constricts slowly and equally to **weak** light directed into **other** eye
			Pupil dilates slowly when **weak** light is removed from eye		Pupil dilates slowly and equally when **weak** light is removed from **other** eye
Natal			Pupil constricts quickly to **strong** light directed into eye		Pupil constricts quickly and equally to **strong** light directed into **other** eye
			Pupil dilates quickly when **strong** light is removed from eye		Pupil dilates quickly and equally when **strong** light is removed from **other** eye
			Late Stage (8-9 months)		**Late Stage (8-9 months)**
			Pupil constricts slowly to **strong** light directed into eye		Pupil constricts slowly and equally to **strong** light directed into **other** eye
Fetal			Pupil dilates slowly when **strong** light is removed from eye		Pupil dilates slowly and equally when **strong** light is removed from **other** eye
			Early Stage (6-7 months)		Early Stage (6-7 months)
			No pupil constriction to **weak** light directed into eye		No pupil constriction to **weak** light directed into **other** eye
			No pupil constriction to **strong** light directed into eye		No pupil constriction to **strong** light directed into **other** eye

1.b. DOLL'S EYE RESPONSES

Stimuli: Passive movement of head against body

Functional Implications: Prepares for voluntary separation of eyes from head
Integrated when eyes and head move together voluntarily

Eyes should not be fixating on a target during the rapid passive head-turning

Developmental Levels		Pattern Components		Pattern Components	
Right	Left	R | L		R | L	
		Direction	**Head Rotation**	Eye	**Head Flexion/Extension**
3 months			Eyes move in same direction as head **rotation**: Integrated		Eyes move in same direction as head **flexion**: Integrated
					Eyes move in same direction as head **extension**: Integrated
2 months			Delayed or inconsistent eye movements in same direction as head **rotation**: Beginning integration		Delayed or inconsistent eye movements in same direction as head **flexion**: Beginning integration
					Delayed or inconsistent eye movements in same direction as head **extension**: Beginning integration
Natal			Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **rotation** during first 10 days, gradually decreasing		Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **flexion** during first 10 days, gradually decreasing
					Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **extension** during first 10 days, gradually decreasing
			Mid Stage (7-8 months)		**Mid Stage (7-8 months)**
Fetal			Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **rotation**		Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **flexion**
					Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **extension**

Assessment Report

SECTION 1. Primarily Involuntary Visual Patterns (Reflexive)

1.a. Pupillary Reactions

Clinical observations: Pupils constrict quickly to strong light, with equal constriction in the opposite eye when either is stimulated (consensual reflex), but constrict slowly to weak light and also show a slow consensual reflex.

Summary and implications for function: Pupillary reactions are not consistent. If reflexive muscles such as the ciliary muscles are delayed, voluntary eye muscles may be even more so. Partially closing one or both eyelids or lowering the head are compensations often used to protect the eyes against too much light, but adequate illumination is necessary for use of residual low vision.

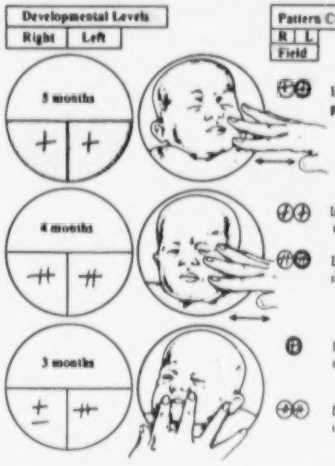
1.b. Doll's Eye Responses

Clinical observations: Delayed eye movements in direction of head flexion, extension, and rotations to right and left

Summary and implications for function: Involuntary eye movements interfere with accurate and functional voluntary control during academic tasks such as reading and writing. Eyes lagging behind head cause delay and inaccuracy when alternating glances between desk and board in the classroom or between a worksheet on the left (since Joseph writes with his left hand) to a book on the right.

1.c. EYELID REFLEXES

	Stimuli	Functional Implications
Defensive Blink to Threat	Rapid approach and removal of visualized target (Small: spread fingers; Large: test booklet)	Protects eyes from tactile assault
McCarthy's Reflex	Light non-visualized tap above one eyebrow (supraorbital area)	Activates unilateral eyelid function
Naso-Palpebral Reflex	Light non-visualized tap on bridge of nose	Activates bilateral eyelid function
Eye-Neck Reflex	Bright light in eyes, head unsupported (flashlight)	Primitive survival reaction
Visuo-Palpebral Reflex	Bright light in eyes (flashlight)	Protects eye from excessive light
Cochleo-Palpebral Reflex	Sharp noise (hand clap)	Protects eye from certain non-visual stimuli



Pattern Components — Field (R | L) — **Defensive Blink to Threat**

Immediate and consistent to small target in peripheral field — detects movement even in functionally blind right field

Immediate and consistent to large target in peripheral field

Delayed or inconsistent to small target in peripheral field

Immediate and consistent to small target in central field

Delayed or inconsistent to large target in peripheral field

Pattern Components — Eye (R | L)

McCarthy's Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap

Naso-Palpebral Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap

Eye-Neck Reflex: integrated in preterm infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backward)

Consistent and equal **eyelid opening** in normal illumination (both fully open)

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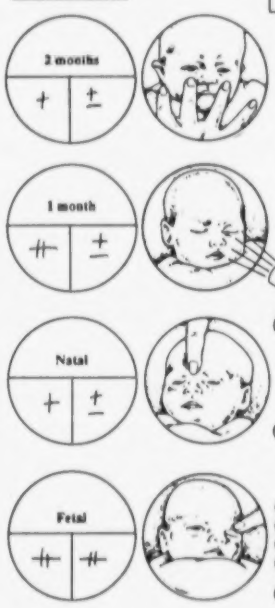
1. c. EYELID REFLEXES



Pattern Components — Field (R | L) — **Defensive Blink to Threat**

Immediate and consistent to large target in central field

Delayed or inconsistent to small target in central field

Delayed or inconsistent to large target in central field

Cochleo-Palpebral Reflex: blinking of both eyes without global responses

Late stage (8-9 months)

Cochleo-Palpebral Reflex: blinking and global startle

Mid stage (7-8 months)

Defensive Blink to Threat

None to **small target in peripheral field**
None to **large target in peripheral field**
None to **small target in central field**
None to **large target in central field**

Early stage (6-7 months)

Cochleo-Palpebral Reflex: mild eyelid flinching

Pattern Components — Eye (R | L)

McCarthy's Reflex: beginning integration, delayed or inconsistent homolateral blink

Naso-Palpebral Reflex: beginning integration, delayed or inconsistent bilateral blink

Inconsistently equal **eyelid opening** in normal illumination

Visuo-Palpebral Reflex: tight eyelid closure

Eye-Neck Reflex: integrated in full-term infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backwards)

Consistently equal **eyelid opening** in subdued light (both fully open)

Visuo-Palpebral Reflex: blinking

Eye-Neck Reflex: opisthotonos (arching backward) strong in first week only

Naso-Palpebral Reflex: blinking of both eyes

Consistent **eyelid opening**, one wider, in subdued light — also, (R) age is small

Late stage (8-9 months)

Visuo-Palpebral Reflex: eyelid tensing and flinching

Eye-Neck Reflex: opisthotonos (arching backward)

Mid stage (7-8 months)

Visuo-Palpebral Reflex: strong frowning or flinching

McCarthy's Reflex: immediate homolateral blink

Inconsistent **eyelid opening**, one wider, in subdued light

Early stage (6-7 months)

Visuo-Palpebral Reflex: mild flinching through closed or semi-closed lids

Eye-Neck Reflex: no response

McCarthy's Reflex: one-eye flinch

Naso-Palpebral Reflex: eyes flinch

No **eyelid opening**, even in subdued light

Assessment Report

1.c. Eyelid Reflexes

Clinical observations: Unequal eyelid opening and closing (left more open than right);

Immediate and consistent defensive blink to targets in central or peripheral fields;

Immediate closure to bright light (visuo-palpebral reflex); automatic bilateral blinking to sharp noise (cochleo-palpebral reflex)

Summary and implications for function: The eyelid blink is important because it protects the eye from danger. Unequal eyelid opening indicates lack of optical and neurological symmetry.

Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)

2. a. LOCALIZATION (VISUAL APPROACH)

Target Size	Focal Lengths	Stimuli
Large: bigger than examiner's hand	Near space: 3-12"	Light
Small: size of hand or smaller	Middle space: 1-6'	Sound
Tiny: pellet size	Far space: 6-20'	Faces
	Distant space: 20'-infinity	Contour
		Movement

Developmental Levels: Right | Left

Pattern Components: R | L; Direction

Eyes localize, then **hand** approaches and contacts tiny target
Eyes move independently from stabilized **head** to localize target
Localizes non-vocalizing **face** in far space on 2nd trial, after 1st trial with sound
Localizes **large target** by **contour/pattern** in **far** space discriminates 4" letters up to 20' away
Some letter configurations more difficult than others
Adjusts **body** position to localize target more easily
Turns to side, then up, to localize non-visualized **sound** above ear
Turns in **arc** movement to localize non-visualized **sound** below ear

Compensates for (R) field deficits by rotating head to the (R) occasionally to bring (L) eye toward (R) field.

Eyes and **hand** pursue lost small target outside visual field
Eyes localize tiny target in near space, without **hand** approach
Eyes begin to move independently from stabilized **head** to localize target
Localizes vocalizing **face** in far space
Localizes large **moving** target in **far** space
Localizes small target by **contour/pattern** in **middle** space discriminates 1½" letters up to 6' only
Turns to side, then down, to localize non-visualized **sound** below ear

Because of visual impairment, needs good illumination and target contrast with background

Eyes localize and **hand** grasps small target in near space
Eyes, not **hand**, pursue lost small target outside of visual field
Smiles at own **face** in mirror spontaneously or when tapped
Localizes large target by **contour/pattern** in **middle** space
From side
From above
From below
Localizes **penlight** moving slowly into peripheral field in an arc 12" away at 90° from central fixation point (tested in subdued light)

Eyes and **head** move together consistently to localize target
Eyes regard own **hand** spontaneously
Prompt regard to target presented **centrally** (in body midline)
Eyes localize and **hand** approaches, contacting small target in near space
Eyes glance briefly at target in own moving **hand**
Localizes large **moving** target in **middle** space
Eyes turn to target with sound properties placed in own hand
Turns toward side of non-visualized **sound** 18" from ear
Localizes non-vocalizing **face** in middle space

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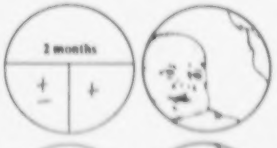
2. a. LOCALIZATION (VISUAL APPROACH)

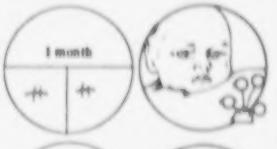
Testing localization to diffuse light. Subject is observed during slow rotation away from light, for head derotation toward light
Testing localization of penlight moving into peripheral field from each side and above. Examiner stands behind subject who is fixating on another target at central fixation point. To test from below: Subject reclines as target is brought upward from feet

Developmental Levels: Right | Left

Pattern Components: R | L; Direction



Eyes glance at own moving **hand/fingers**
Delayed regard to target presented **centrally** from below (viewed at chest level)
Turns to target in **peripheral** surroundings
Localizes **penlight** moving slowly into peripheral field in an arc 12" away at 30° from central fixation point
Localizes small target with internal **movement** up to 3' away
Localizes large target with internal **movement** in **middle** space
Localizes non-vocalizing **face** in **near** space
Localizes vocalizing **face** in middle space
Turns toward general direction of non-visualized **sound** source



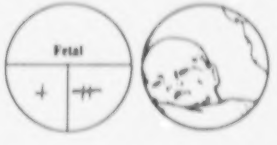
Eyes and **head** move together inconsistently during voluntary movements
Localizes diffuse **light** source
Localizes small target with internal **movement** up to 12" away
Brief glances at large target with internal **movement** in **middle** space
Brief regard of non-vocalizing **face** in near space
Localizes vocalizing **face** in **near** space

Random **eye** movements, not together with random **head** and **body** movements
Diffuse distractibility to target in **peripheral** surroundings
Turns toward large **areas** of **light**
Localizes small target with internal **movement** exactly 8" away

Late Stage (8-9 months)

Turns toward diffuse **light**
Faint interest in **peripheral** surroundings
Localizes focalized **light** (penlight) moving into peripheral field at central fixation point
Widens eyes and **attends** to pleasant non-visualized **sound** without head turning

Early Stage (6-7 months)



No response to visual target
No head turning toward diffuse **light**
Involuntary **eyeball** movements in all directions, even under closed lids
Mild eyelid flinching to non-visualized **sound**
No head-turning toward focalized **light**

Assessment Report

SECTION 2. Primarily Voluntary Eye Movements (Cognitively Directed)

2.a. Localization (Visual Approach)

Clinical observations: Eyes and head move directly to sound in all areas just outside of the visual field;

Immediate localization of penlight moving into upper and lower visual fields, but delayed in left and right peripheral fields;

Highly attracted by moving targets;

Immediate attention to mirror image and nonvocalizing faces in near and middle space; localizes, approaches, and contacts tiny target in near or middle space, left hand better than right

Summary and implications for function: Localization skills are Joseph's greatest visual strength, but his tendency to respond to any and all auditory and animate visual environmental stimuli frequently interfered with his concentration and attention to the task at hand. Difficulty locating targets in far space and peripheral fields by pattern/contour alone was an obstacle to efficient mobility in the community.

General goal: Improve localization to targets in peripheral fields by teaching eye-hand scanning movements to compensate for field deficits

Model for Management of Visual-Motor Dysfunction: (fig. 8-1)

Individualized Management Program

Community Domain

Goal: To improve money skills

Objective: When asked for a dollar, Joseph will give the correct amount using three equivalencies (for example, four quarters, one bill, ten dimes) with 100% accuracy for six trials.

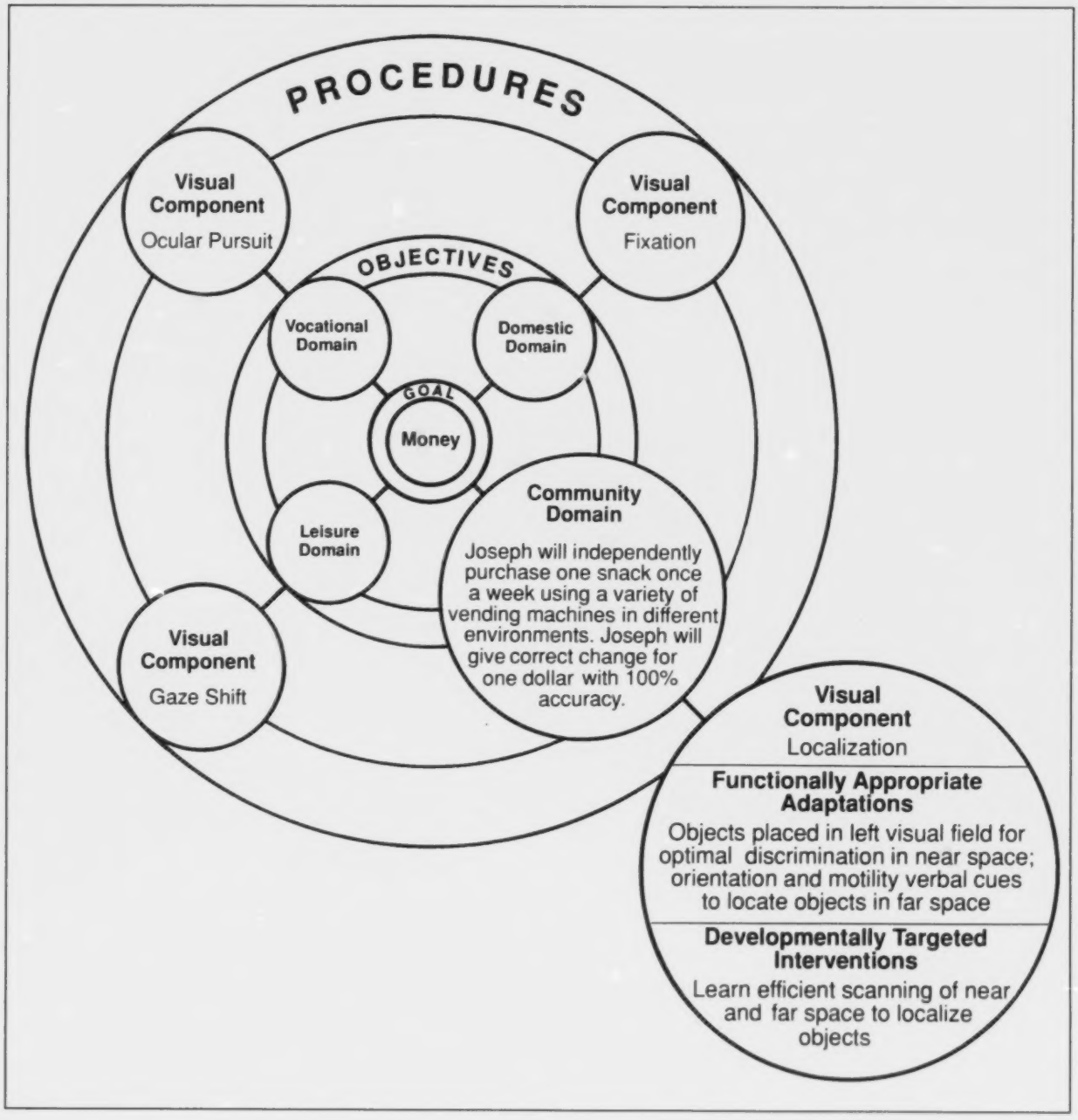

PROCEDURES
Visual Component
Ocular Pursuit
Visual Component
Fixation
OBJECTIVES
Vocational Domain
Domestic Domain
GOAL
Money
Leisure Domain
Community Domain
Joseph will independently purchase one snack once a week using a variety of vending machines in different environments. Joseph will give correct change for one dollar with 100% accuracy.
Visual Component
Gaze Shift
Visual Component
Localization
Functionally Appropriate Adaptations
Objects placed in left visual field for optimal discrimination in near space; orientation and motility verbal cues to locate objects in far space
Developmentally Targeted Interventions
Learn efficient scanning of near and far space to localize objects

Fig. 8-1

Model for Management of Visual-Motor Dysfunction: Community Domain

Objective: Joseph will independently purchase one snack once a week using a variety of vending machines in different environments.

Visual Component: Localization

Visual Present Level of Function: Joseph can localize all targets in his central field (straight ahead and within near space of 12") but ignores those in his peripheral fields (especially the right) unless they make noise or are moving. Because of Joseph's limited visual fields as well as acuity deficits (low vision), he localizes small targets in middle space (1' to 6') and large targets in far space (6' to 20') by their sound or movement properties, not by contour/pattern only.

Visual Procedures

Functionally Appropriate Adaptations: During classroom situations, coins should be placed in Joseph's left central visual field for optimal performance in localizing and discriminating correct amounts (fig. 8-2).

During school or community situations, the vision consultant can train Joseph's classroom aide to provide orientation and mobility (O & M), verbal cues to help him locate a vending machine until he reaches within six feet (figs. 8-3, 8-4).

Developmentally Targeted Interventions: Joseph needs to improve his awareness of left peripheral and right central and peripheral fields. In a one-to-one session with his special education teacher, coins can be placed across a wide area, requiring Joseph to localize the correct ones from the entire 180-degree horizontal field, using scanning movements of eyes and head together (fig. 8-5).

Fig. 8-2

Fig. 8-3

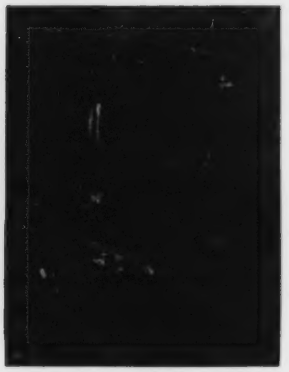


Fig. 8-4

Fig. 8-5

Joseph needs to expand his localization skills into far space, where he is able to discriminate targets once he has located them. Searching and scanning with eye-head movements can be practiced while riding the tractor with his father on the farm as he points to his mother bringing lunch to the field (fig. 8-6).

Fig. 8-6

2. b. FIXATION (VISUAL GRASP)

Modes of Visual Processing
Ambient: passive stare, with awareness of surroundings Focal: active focus on target, excluding surroundings

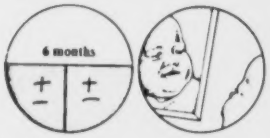
Approximate Functional Focal Lengths		
Near Space: 3-12"	Middle Space: 1-6'	Far Space: 6-20'

Developmental Levels	
Right	Left

Pattern Components	
R	L
Field (Both Eyes)	

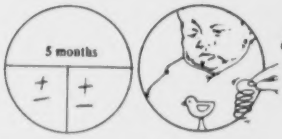
Pattern Components	
R	L
Eye (Other Occluded)	

NOT APPLICABLE

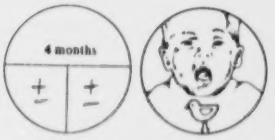


Intense **focal** fixation with visual responses, global suppressed
Inspects own **face** in mirror intently
Eyes fixate on tiny target while **hand** approaches and contacts
Fixates at **focal lengths**: 3" - 20' able to count garage windows in distant space after assistance in localizing

(No functional reason in (R) eye)



Maintains **focal** fixation with more visual than global responses
Maintains fixation on stationary target in competition with **moving** one
Intermittent regard of own **face** in mirror
Eyes fixate on tiny target without **hand** approach
Fixates on **focal lengths**: 3" - 6'
Compensates for (R) eye and (R) Field deficits by keeping head rotated to the (R) and tilted downward to the (L)



Efficient **ambient** inspection of surroundings in middle and far space
Eyes maintain fixation on small target in **hand**
Prolonged, selective **focal** fixation with multiple global responses
Uses **ambient** stare/ fixation on surroundings to rest from intense focal fixation
Consistent **binocular fixation**
Eyes fixate recurrently and with delay on tiny target without **hand** approach
Fixates at **focal lengths**: 4" - 5'
Constant head movements interfere with prolonged fixation, as well as random eye movements, horizontal and vertical, and nystagmus, which increase upon effort to fixate

Maintains fixation on non-vocalizing **face** for 10 seconds
Crude **ambient** inspection of surroundings in middle and far space
Direct, discriminative **focal** fixation on target in midline
Inconsistent **binocular fixation**
Eyes fixate briefly on small target placed in own **hand**
Prolonged fixation on target with rhythmical movement
Maintains fixation on stationary target unless distracted by moving one
Fixates at **focal lengths**: 5" - 3'

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2. b. FIXATION (VISUAL GRASP)

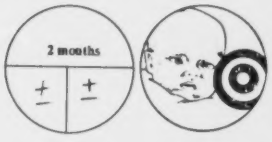
Fixation Criteria (Global responses mature to visual only)	
Global Eyes and mouth open, increased or decreased respiration, muscle tone, or body activity	Visual Pupils constricted, eyes round rather than oval, upper eyelids tensed and raised, eyes relatively immobile

Developmental Levels	
Right	Left

Pattern Components	
R	L
Field (Both Eyes)	

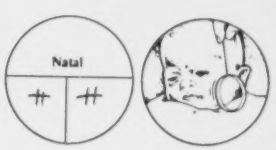
Pattern Components	
R	L
Eye (Other Occluded)	

NOT APPLICABLE

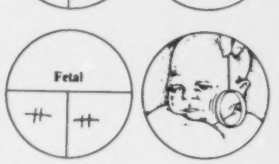


Direct discriminating **focal** fixation on target at the side of midline
Maintains fixation on vocalizing **face** for 10 seconds
Beginning **binocular fixation** with blinking and overconvergence
Eyes regard **hand** in ATNR position (head facing extended arm, other flexed)
Fixates longer on black and white bull's eye **pattern** than stripes
Fixates at **focal lengths**: 6" - 2'
Loses fixation frequently, eyes drift away

Brief **focal** fixation on target at the side of midline
Fleeting regard of non-vocalizing **face**
Brief fixation on vocalizing **face** for 2-3 seconds
Defined **monocular fixation**: active eye fixates on target, other shifts ~~nasally~~ temporally
Bi-ocular fixation (alternating monocular): fixation alternates rapidly between both eyes, which shift with head in rhythmical lateral excursions
Roving eyes become relatively immobile, with **ambient** stare at surroundings
Fixates longer on black and white stripes than bull's eye **pattern**
Fixates at **focal lengths**: 7" - 12"
(L) eye fixates only



Tries to achieve **focal** fixation on target at side of midline, with some global responses
Vague, intermittent, **ambient** regard of surroundings
Crude **monocular fixation**: active eye aligns, tries to immobilize and fixate momentarily on target while inactive eye closes or deviates nasally or temporally
Regards target with internal **movement** placed in line of vision
Maintains **ambient** gaze toward diffuse light by turning head when slowly rotated away
Fixates longer on black and white **pattern** than on target without pattern/contrast
Fixates at **focal length**: 8"



Late stage (8-9 months)
Immobilizes eyes briefly in pseudo-fixation (diffuse, passive, **ambient**)
Mid stage (7-8 months)
Briefly alert to target with **movement** properties (agitated or dangling)
Early stage (6-7 months)
No **focal** fixation
No immobilization of eyes in **ambient** stare at surroundings
No **ambient** gaze toward light

Assessment Report

2.b. Fixation (Visual Grasp)

Clinical observations: Defined monocular fixation with left eye, none with right eye (no binocular fixation);

Efforts to maintain fixation on near target include global responses of increased muscle tone and increased nystagmus;

Most prolonged fixation on targets with internal movement placed in line of vision in near space;

No prolonged, discriminating regard of vocalizing or nonvocalizing faces (eyes drift away easily), mirror image (intermittent rather than intent inspection), or other targets in near, middle, or far space (constant head movements interfere with sustained fixation);

Difficulty maintaining fixation on stationary target in competition with moving one, but can achieve for short periods with cognitive effort;

Crude, roving ambient inspection of middle and far space; uses a starey, passive fixation on surroundings to rest eyes

Summary and implications for function: Joseph's difficulty immobilizing his eyes (short fixations) has implications for social skills (poor eye contact), academics (brief inspection and discrimination of educational materials), and general attention to tasks (unable to ignore extraneous stimuli). Although visual fatigue occurs frequently, the system can recuperate rapidly if rests are provided; thus sustained work periods may not be appropriate.

General goal: Increase duration and efficiency of fixations

Model for Management of Visual-Motor Dysfunction (fig. 8-7)

Individualized Management Program

Domestic Domain

Goal: To improve time-telling skills

Objective: Joseph will identify digital time from the half-hour to the hour randomly by reading his watch.

Goal: To improve cooking skills

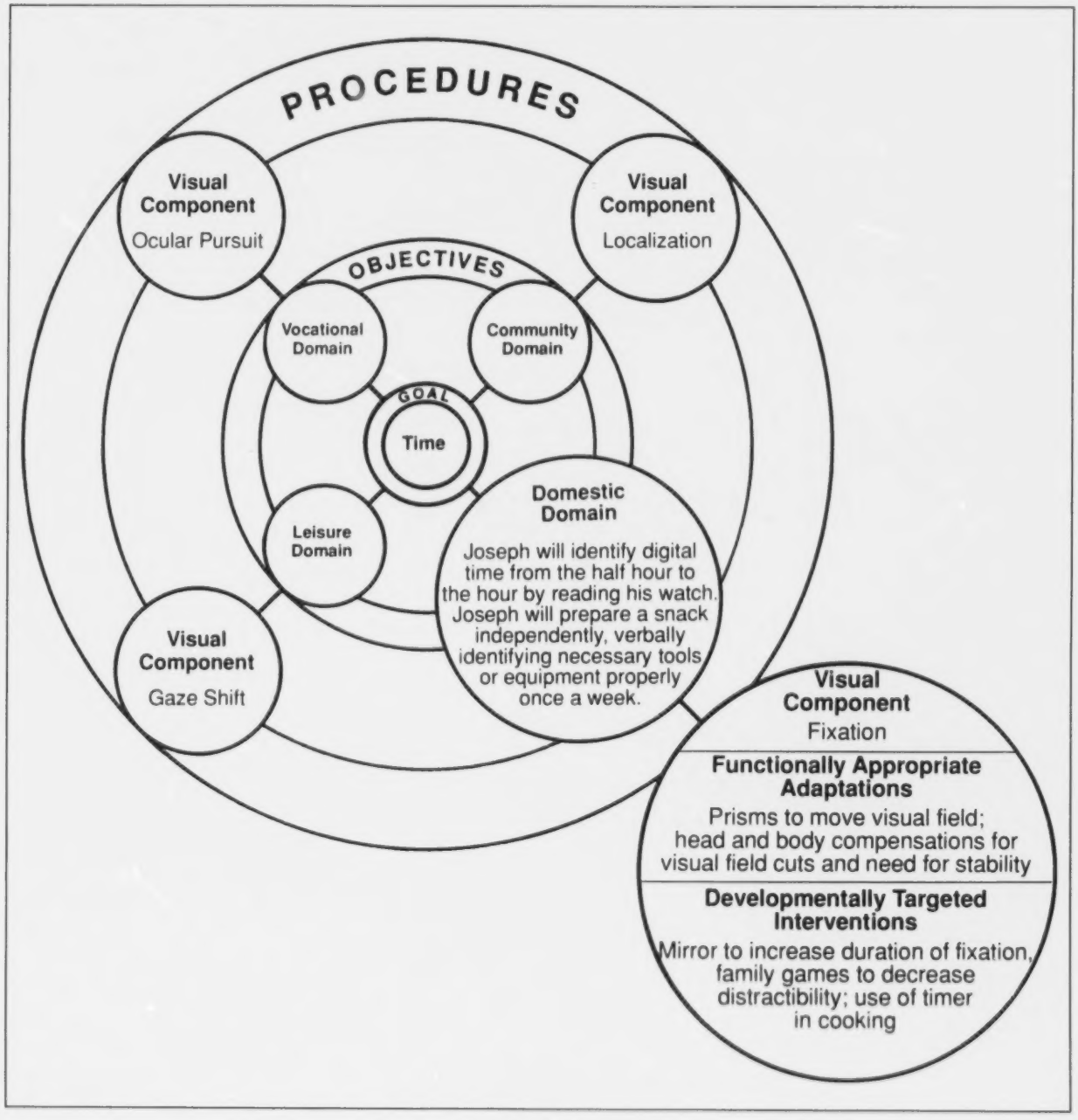

PROCEDURES
Visual Component
Ocular Pursuit
Visual Component
Localization
OBJECTIVES
Vocational Domain
Community Domain
GOAL
Time
Leisure Domain
Domestic Domain
Joseph will identify digital time from the half hour to the hour by reading his watch. Joseph will prepare a snack independently, verbally identifying necessary tools or equipment properly once a week.
Visual Component
Gaze Shift
Visual Component
Fixation
Functionally Appropriate Adaptations
Prisms to move visual field; head and body compensations for visual field cuts and need for stability
Developmentally Targeted Interventions
Mirror to increase duration of fixation, family games to decrease distractibility; use of timer in cooking

Fig. 8-7

Model for Management of Visual-Motor Dysfunction: Domestic Domain

Fig. 8-8

Objective: Joseph will prepare a simple snack independently, verbally identifying necessary tools or equipment properly once a week.

Visual Component: Fixation

Visual Present Level of Function: Unless Joseph's entire body is stabilized (usually in a flexed posture, even in standing), his eyes are able to fixate only briefly for discrimination of a target (fig. 8-8). He holds his head rotated to the right and tilted downward to the left during fixation on his mother's face in an attempt to compensate for his right hemianopsia (visual field loss in the nasal portion of his left eye and the temporal portion of his right) as well as the cataract in his right eye (Fig. 8-9).

Fig. 8-9

Visual Procedures

Functionally Appropriate Adaptations: During fixation in activities such as hammering nails with his father, Joseph needs to be allowed to compensate for his visual field loss by optimally positioning the residual temporal field of his left eye (fig. 8-10). New prescriptive lenses have included prisms that are designed to move his visual field more to midline and additional prisms to rotate the

Fig. 8-10

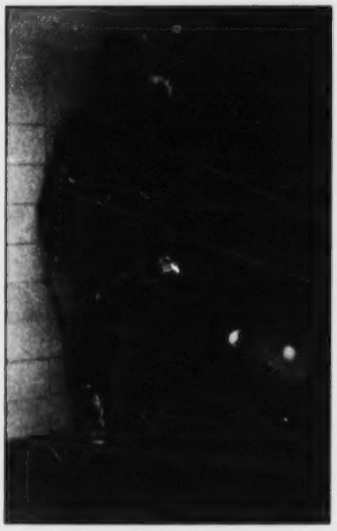


Fig. 8-11

field. Joseph needs to be instructed by his physical therapist in methods to stabilize eyes, head, and body postures as normally as possible. For example, standing positions should be erect, using a wall if possible, or leaning appropriately on his crutches, with the target (his watch on left wrist) in near space in his left visual field (figs. 8-11, 8-12).

Fig. 8-12

Developmentally Targeted Interventions: Joseph needs to increase the length and efficiency of his fixations for discrimination in his home environment. Watching himself sing in a mirror (vocalizing face) can help maintain the fixation skills needed for future grooming skills such as shaving. The ability to concentrate despite distractions from moving objects can be developed by games in which family members try to gain Joseph's attention while he attempts to complete a task within a given amount of time. During cooking activities, he can read the numbers on a timer, then set the dial to determine how much time is needed for tasks such as boiling, whipping, or baking.

2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

Approximate Functional Focal Lengths	
Near Space: 3 - 12"	Far Space: 6 - 20'
Middle Space: 1 - 6'	Distant Space: 20' - infinity

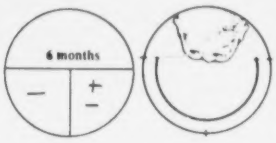
Compensatory Eye Movements: Eyes remain on stationary target during active head movements

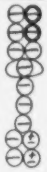
Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction (Both Eyes)	

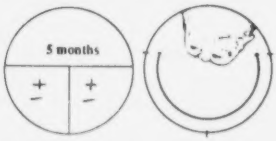
Pattern Components	
R	L
Eye (Other Occluded)	

NOT APPLICABLE



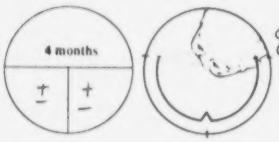


Eyes move independently from **head** to extreme right/left fields while tracking
Tracks target **horizontally 180°** smoothly at all speeds, **focal length 3" - infinity**
Tracks in **circular** direction smoothly at all speeds and focal lengths
Tracks **vertically upward** smoothly at all speeds and focal lengths
Tracks **vertically downward** smoothly at all speeds and focal lengths
Smooth **convergence** from far to near space
Smooth **divergence** from near to far space
Tracks **diagonally upward** with midline pause to refixate
Tracks **diagonally downward** with midline pause to refixate

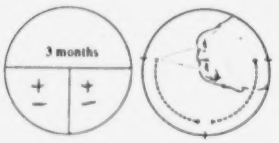


Moves head to the (R) to follow target

Eyes begin to move independently from **head** to limited upper/lower fields
Tracks target **horizontally 180°** without midline jerk, **focal length 3" - 6'**
Continuous **diagonal** tracking **downward** with some jerky movements
Smooth **convergence** from far to middle space



Eyes begin to move independently from **head** to limited right/left fields
Tracks target **horizontally 180°** with midline jerk, **focal length 4" - 5'**
Continuous **circular** tracking with some jerky movements
Continuous **vertical** tracking **downward** with some jerky movements
Continuous **diagonal** tracking **upward** with some jerky movements
Smooth **divergence** from middle to far space



Tracks target **horizontally 180°** continuously, overshooting, with midline pause and re-localization, **focal length 5" - 3'**
Tracks, lingers, and visually searches for target at point of disappearance
Continuous **vertical** tracking **upward** with some jerky movements
Beginning **vertical** tracking **downward**, in series of jerky movements, losing and regaining target
Beginning **diagonal** tracking **upward**, in series of jerky movements, losing and regaining target
Continuous **convergence** with some jerky movements from middle to near space
Continuous **divergence** with some jerky movements from near to middle space
Compensatory Eye Movements: eyes remain on stationary target consistently during rapid and extensive voluntary head movements

---

2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

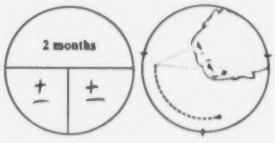
Tracking Movements	Vergence Movements
Eyes remain on target during horizontal, vertical, circular, and diagonal movements	Eyes remain on target during convergence and divergence in all focal lengths

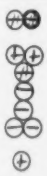
Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction (Both Eyes)	

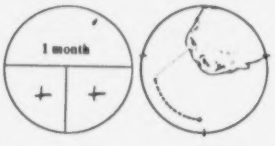
Pattern Components	
R	L
Eye (Other Occluded)	

NOT APPLICABLE

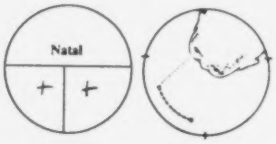


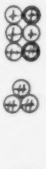


Tracks target **horizontally 90°** slightly past midline, jerky movements, poor regulation of eye speed to target speed, **focal length 6" - 2'**
Beginning **circular** tracking in series of jerky movements, losing and regaining target loses at longer (R)
Beginning **vertical** tracking **upward** in series of jerky movements losing and regainingtarget
Beginning **convergence** with short jerks, blinking, and overconvergence within near space
Beginning **divergence** with short jerks, blinking, and overdivergence within near space
Compensatory Eye Movements: eyes remain on stationary target inconsistently during rapid and extensive voluntary head movements
Follows target longer during **approach** than **retreat**

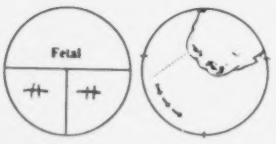


Tracks target **horizontally 60°** from periphery to midline and back to side, jerky movements, **focal length 7 - 12"**
Follows target equal distance during **approach** and **retreat**
Compensatory Eye Movements: eyes remain on stationary target during moderate speed and excursions of voluntary head movements





Eyes and **head** move together during tracking
Eyes and **head** move randomly in short lateral excursions
Tracks target **horizontally 45°** in peripheral field, in series of jerky movements, losing target frequently, dufficulty regaining, **focal length 8"**
Follows target longer during **retreat** than **approach**, between 8 and 12"
Compensatory Eye Movements: eyes remain on stationary target during very slow voluntary head movements in limited range



Late Stage (8-9 months)
Tracks slowly moving target with internal movement horizontally 30° in peripheral field in near space, constantly losing target, able to regain if target pauses
Mid Stage (7-8 months)
Momentary afterpursuit of slowly moving target with internal movement (fluttering fingers)
Early Stage (6-7 months)
Eyes move without purpose, separate from **head**, even under closed lids
No response to visual target

Assessment Report

2.c. Ocular Pursuits (Visual Manipulation)

Clinical observations: Poor horizontal tracking, with jerky movements, poor regulation of eye speed to target speed, loss of target and difficulty regaining it, eyes moving together with head rather than separately;

Fair vertical tracking; he attempts circular tracking but loses target moving counterclockwise in lower right field;

Difficulty with diagonal tracking (upward to the right: none; upward to the left: eyes close and roll upward; downward to the right: moves head to avoid crossing midline; downward to the left: adequate);

No functional convergence or divergence;

Eyes remain on stationary target during moderate speed and excursions of head movements (compensatory eye movements)

Summary and implications for function: Since the quality of eye movements reflects that of the entire body, visual sensory input as well as visual motor output cannot be consistent, smooth, and accurate when an individual's head and body are in constant motion. Eye movements are slower and less efficient when they are always linked to head movements, but separation is not developmentally nor functionally appropriate for Joseph, and thus not a realistic short-term goal.

General goal: Improve ocular pursuit, eyes and head together

Model for Management of Visual-Motor Dysfunction (fig. 8-13)

Individualized Management Program

Vocational Domain

Goal: To improve writing skills

Objective: Joseph will write full name, address, and telephone number on top of his papers with 100% accuracy three times a week.

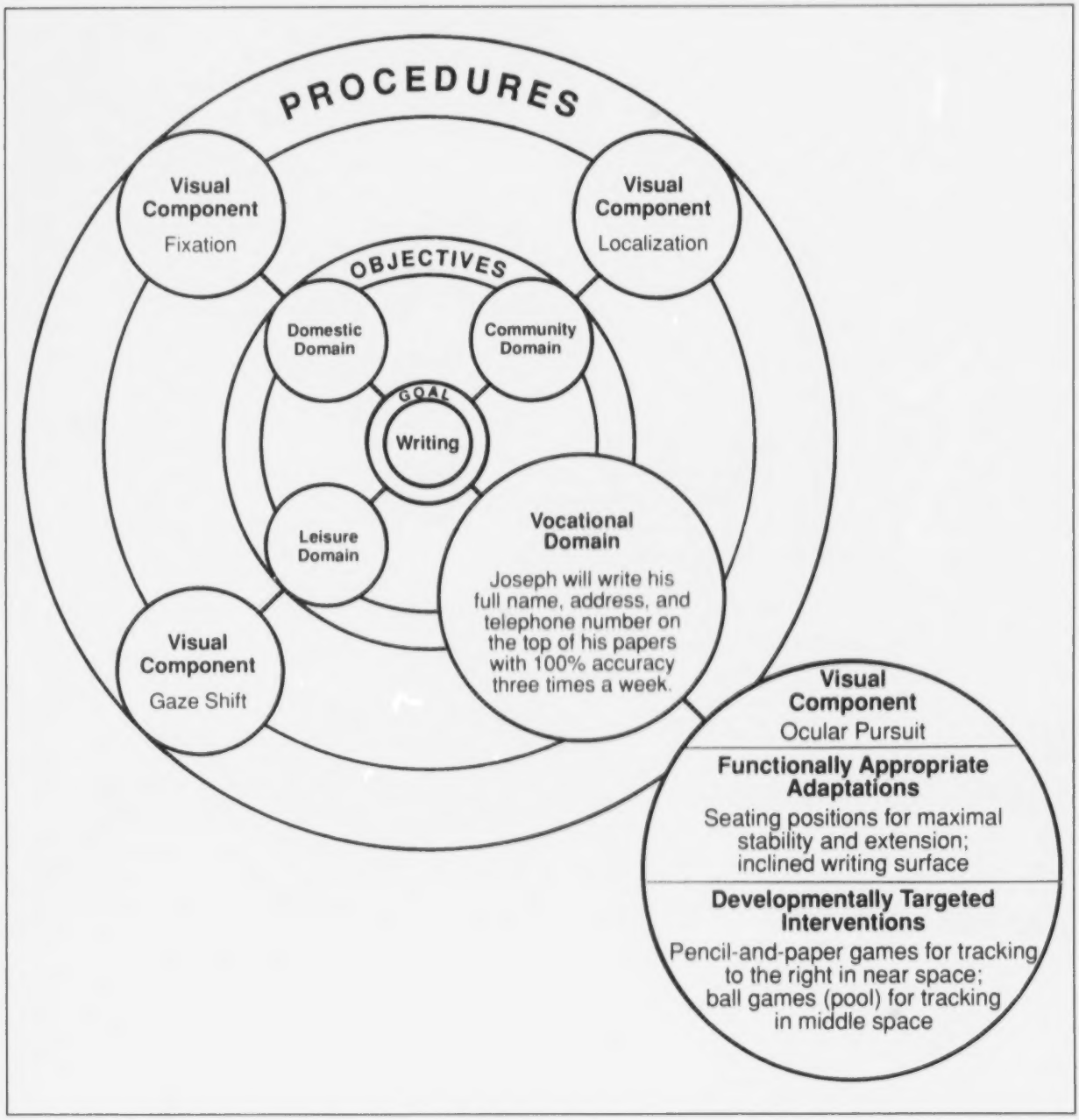

PROCEDURES
Visual Component
Fixation
Visual Component
Localization
OBJECTIVES
Domestic Domain
Community Domain
GOAL
Writing
Leisure Domain
Vocational Domain
Joseph will write his full name, address, and telephone number on the top of his papers with 100% accuracy three times a week.
Visual Component
Gaze Shift
Visual Component
Ocular Pursuit
Functionally Appropriate Adaptations
Seating positions for maximal stability and extension; inclined writing surface
Developmentally Targeted Interventions
Pencil-and-paper games for tracking to the right in near space; ball games (pool) for tracking in middle space

Fig. 8-13

Model for Management of Visual-Motor Dysfunction: Vocational Domain

Objective: Joseph will use functional one-to-one correspondence in classroom and other environments with other people 80% of the time.

Visual Component: Ocular pursuit

Visual Present Level of Function: Joseph's horizontal eye movements while tracking the moving pencil during writing activities are jerky and irregular, with poor regulation of eye speed to target speed. His entire body is totally flexed for maximal stability during eye-head mobility. He holds his head close to the paper (at the null point) to dampen the nystagmus as much as possible (fig. 8-14).

Fig. 8-14

Visual Procedures

Functionally Appropriate Adaptations: During classroom situations, Joseph needs an erect sitting position in an appropriate chair facilitating spinal extension and pelvic alignment, with forearms stabilized on an elevated surface within a 12-inch focal length to allow smooth mobility of his eyes, head, and writing arm. An inclined surface suggested by his occupational therapist brings his face parallel to the paper and facilitates neck and spinal extension (fig. 8-15). Joseph's posture improves even more when a computer monitor screen requires vertical orientation of his face (fig. 8-16).

Fig. 8-15

Fig. 8-16

Developmentally Targeted Interventions: Joseph needs to improve ocular pursuit in near space, especially to the right, as he watches his moving pencil. He can play a connecting dots game with his brother, with dots numbered from left to right, counting them in a one-to-one correspondence, simulating the motor activity of writing, but with a lower level cognitive component (fig. 8-17).

Fig. 8-17

He and his brother can also play pool. Joseph can follow the path of each ball hit, approaching and retreating, as well as horizontally, in middle space (fig. 8-18).

Fig. 8-18

2. d. GAZE SHIFT (VISUAL RELEASE)

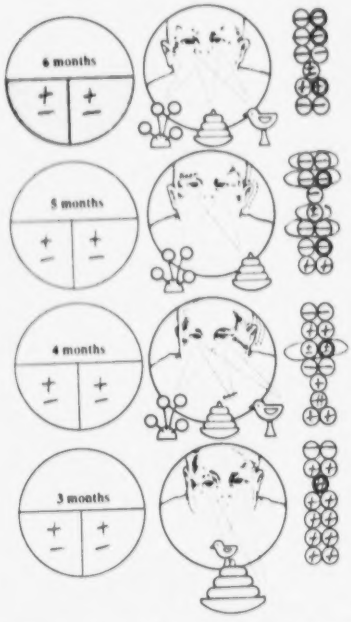
Developmental Levels	
Right	Left

Pattern Components
R | L
Direction

Functional Focal Lengths
Near space: 3 - 12"
Middle space: 1 - 6'
Far space: 6 - 20'
Distant space: 20' - infinity

Shift Gaze: eyes move from one target to another within same focal length or between different focal lengths

Alternate Glance: between 2 targets
Scanning: between 3 or more targets



Scans 3 or more targets within **all focal lengths** quickly and accurately
Eyes move independently from **head** to shift gaze
Alternates glance between 2 targets in **same focal length** within **far space** easily
Shifts gaze between targets in **near** and **far space** quickly and accurately
Shifts gaze within and between **all** focal lengths without **blinking**
Shifts gaze easily during adaptive interaction of **eye/hand/mouth**: regards target, grasps, mouths, withdraws, regards, manipulates, releases, resecures, etc.
Gaze shift easier between different focal lengths than within same because no need to move head
Alternates glance between 2 targets in **same focal length** within **middle space** easily
Alternates glance between 2 targets in **same focal length** within **near space** easily
Shifts gaze between targets in **middle** and **far space** accurately
Shifts gaze between targets in **near** and **middle space** accurately
Scans 3 or more targets in **middle space** quickly but inaccurately
Eyes begin to move independently from **head** to shift gaze
Shifts gaze between **near** and **far space** (releases fixation) during adaptive interaction of **eye/hand/mouth** (grasping, manipulating, mouthing target)
Extends head to shift from target in lower near space to upper middle space, eyes move with head
Conjugate Deviations: eyes consistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **far space** inaccurately
Scans 3 or more targets in **near space**, overshooting, re-localizing
Tenacious fixation interferes with smooth release (**alternate glance**) in **near space**
Shifts gaze between targets in **near** and **middle space** inaccurately
Shifts gaze between targets in **near** and **far space** with **blinking** and eye-rolling
No tenacious fixation, so no need for blinking to release
Shifts gaze from **surroundings** to target in own **hand** after mouthing
Random head movements interfere with accurate shifts.
Conjugate Deviations: eyes inconsistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **middle space** inaccurately
Begins to shift gaze between targets in near and middle space slowly, with difficulty
Eyes and **head** move together consistently during voluntary gaze shifts
Shifts gaze between own **hand** and target during approach
Alternates glance between target placed on surface and **hand** withdrawn
Shifts gaze consistently without **blinking** between targets in same focal length
Compensates for (R) eye and (R) field deficits with head positioning

---

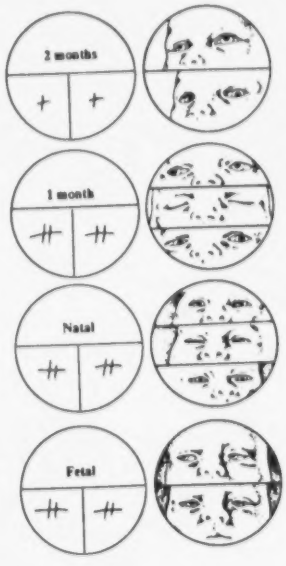
2. d. GAZE SHIFT (VISUAL RELEASE)

Conjugate Deviations: eyes move together in same direction at same time (yoked)

Components of Gaze Shift (Alternate Glance or Scanning)
1. Release of fixation on target
2. Re-localization on next target
3. Repeat

Developmental Levels	
Right	Left

Pattern Components
R | L
Direction



Conjugate Deviations: eyes move voluntarily more than involuntarily (randomly)
Conjugate Deviations: eyes move separately during primarily voluntary gaze shifts
Shifts gaze in **same focal length** in **near space**, inaccurately, overshooting target
Shifts gaze from own **hand** to **surroundings** (releases fixation)
Shifts gaze consistently without **blinking** during involuntary gaze shifts
Shifts gaze inconsistently without **blinking** during voluntary gaze shifts (release of focal fixation)

Conjugate Deviations: eyes move separately during beginning voluntary gaze shifts
Conjugate Deviations: eyes move together during primarily involuntary gaze shifts
Eyes and **head** move together inconsistently during beginning voluntary movements
Blinks consistently during release of ambient fixation (stare at surroundings)

Conjugate Deviations: eyes move together during involuntary gaze shifts
Eyes and **head** move together during random movements of both
Blinks inconsistently during release of ambient fixation (stare at surroundings)

Mid Stage (7-8 months)

No **eye/hand** interaction during eye movements
Random, sluggish **blinks** during eye movements
Involuntary gaze shifts between **different focal lengths**
Involuntary gaze shifts in **same focal length**

Early Stage (6-7 months)

Conjugate Deviations: eyes move co-jointly in all directions during involuntary movements even under closed lids
Eyes move independently from **head** during random movements of both

Assessment Report

2.d. Gaze Shift (Visual Release)

Clinical observations: Inaccurate gaze shifts in same focal length, with overshooting, eyes and head always moving together;

Eyes do not move together consistently (poor conjugate deviations);

Poor scanning of three or more targets, losing fixation and relocalizing;

Shifts gaze from one focal length to another more easily than in same focal length, possibly because no head movement is required

Summary and implications for function: Lack of voluntary eye-head separation prevents rapid efficient eye movements for alternating glances and scanning needed for reading and other classroom visual skills. Reading, which is a series of gaze shifts (movements and pauses), is inefficient when eyes can't move rapidly and separately from head. Inaccurate and slow gaze shifts from book to worksheet or from one place on the page to another may cause the student to lose his place and have difficulty regaining it. The effort required to function with an imperfect visuo-motor system can result in a lower threshold of visual as well as general fatigue, manifested by distractibility or noncompliance.

General goal: Improve accuracy of scanning movements simulating reading

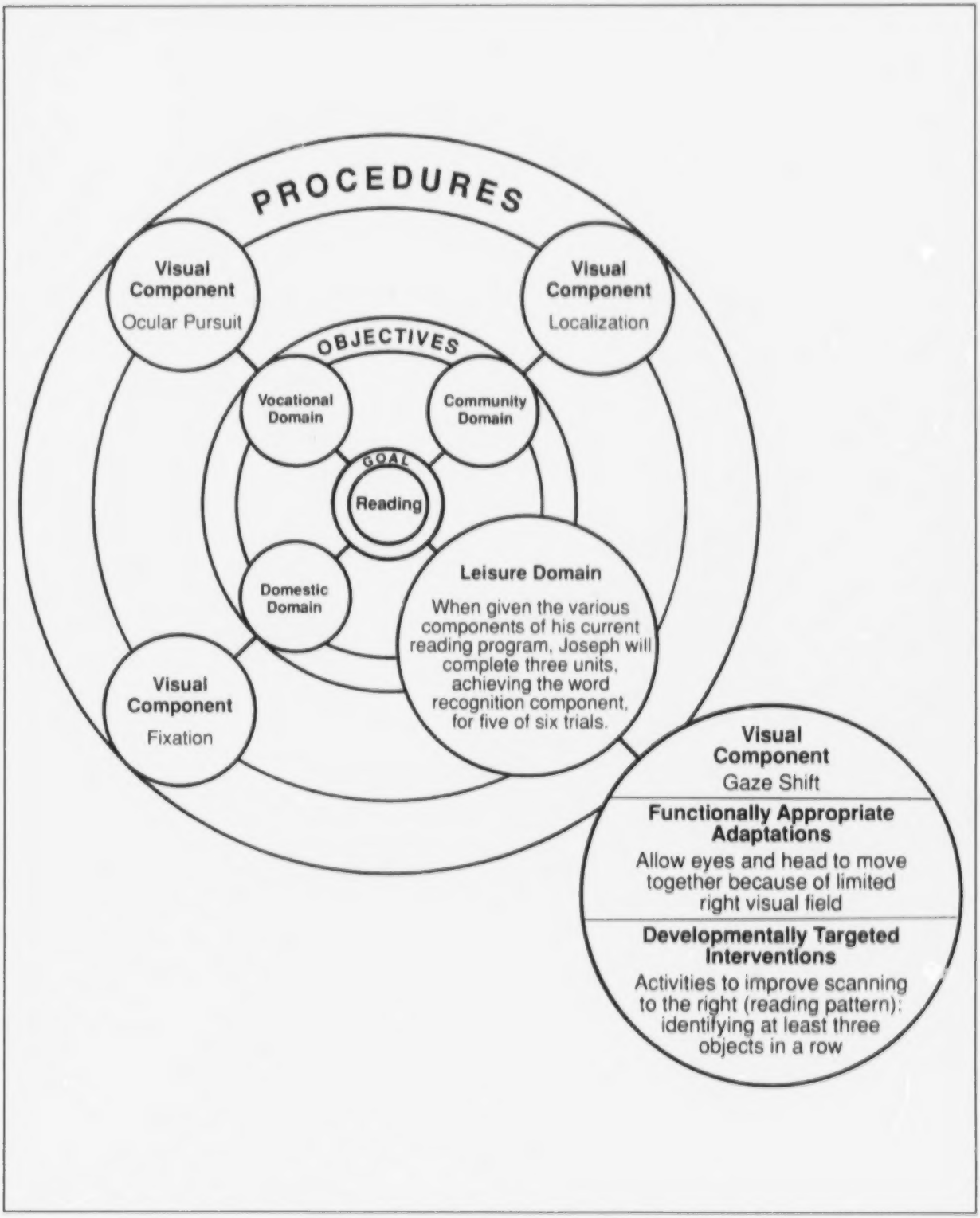

PROCEDURES
Visual Component
Ocular Pursuit
Visual Component
Localization
OBJECTIVES
Vocational Domain
Community Domain
GOAL
Reading
Domestic Domain
Leisure Domain
When given the various components of his current reading program, Joseph will complete three units, achieving the word recognition component, for five of six trials.
Visual Component
Fixation
Visual Component
Gaze Shift
Functionally Appropriate Adaptations
Allow eyes and head to move together because of limited right visual field
Developmentally Targeted Interventions
Activities to improve scanning to the right (reading pattern): identifying at least three objects in a row

Fig. 8-19

Model for Management of Visual-Motor Dysfunction: Leisure Domain

Model for Management of Visual-Motor Dysfunction (fig. 8-19)

Individualized Management Program

Leisure Domain

Goal: To improve reading skills

Objective: When given the various components of his current reading program, Joseph will complete three units, achieving the word recognition component for five of six trials before moving on to the next word.

Visual Component: Gaze shift

Visual Present Level of Function: Joseph's eyes are unable to move rapidly and separately from his head during reading, which is a series of scanning movements or gaze shifts.

Visual Procedures

Functionally Appropriate Adaptations: During reading, Joseph's eyes and head need to move together because of his limited right visual field (figs. 8-20, 8-21, 8-22).

Developmentally Targeted Interventions: Joseph needs to improve accuracy and speed of shifting gaze to the right as his eyes and head scan from one word to the next, and of relocalizing to the left as his eyes and head return to the beginning of the next line. Three *familiar* objects such as kitchen utensils can be arranged in a row in near space for Joseph to identify as his mother points to each, in a left-to-right progression of 1, 2, 3, back to 1, and so on. Three large bright magnets can be arranged on the stove in middle space for him to identify as his mother points to each. At school he can be asked to identify the colors of three cars parked outside the window in the same progression (far space). These activities simulate the motor activity of reading, with lower level cognitive components.

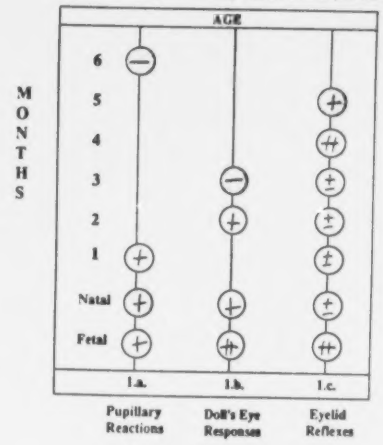
Fig. 8-20

Fig. 8-21

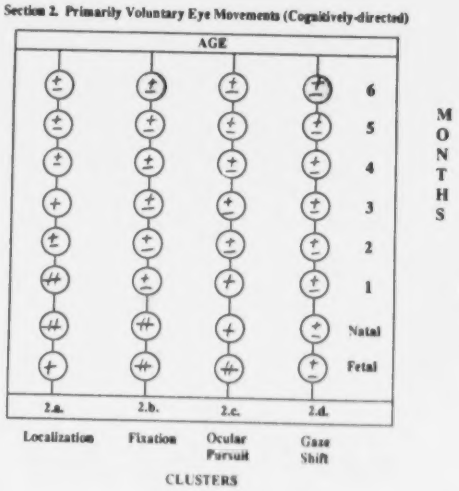
Fig. 8-22

Score Sheet (Developmental Levels)

Section 1. Primarily Involuntary Visual Patterns (Reflexive)



Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)



Summary

Periodic Blink: _____ per minute
SECTION 1. Primarily Involuntary Visual Patterns (Reflexive) 0-5 months
SECTION 2. Primarily Voluntary Eye Movements (Cognitively-directed) 1-6 months

Subject: Joseph N. Examiner: Erhardt Test Date: 8/4/86

Birthdate: 12-7-74 Chronological Age: 11½ years Diagnoses: Cerebral Palsy, Optic Nerve Atrophy, Right Hemianopsia, Right Eye Cataract

Assessment Report

Summary and conclusions: Some reflexive immaturity affects Joseph's functional vision as involuntary doll's eye responses interfere with accurate eye-head shifts. Strong automatic defensive blinks, however, indicate integration of primitive tactilely stimulated reflexive blinks and are important for safety. Unequal eyelid opening indicates optical and neurological asymmetry.

Joseph's ability to localize quickly to sound and movement is one of his strengths, but it sometimes interferes with concentration and attention to task. Delayed localization to light in peripheral fields is related to visual field deficits defined by previous testing (use of 90 degrees only, 45 degrees on each side of midline, O.S., and 45 degrees only on left side of midline, O.D.). Identification of stationary, soundless objects by contour only, especially in middle and far space, is difficult unless Joseph takes time to scan the entire visual field carefully.

Monocular fixation with the left eye is accompanied by head rotation to the right and a lateral tilt to the left, an apparent attempt to bring his functional left eye into the center of his limited visual field and to rotate the primarily vertical orientation into a more horizontal one. Essentially no functional vision is present in the right eye, which deviates outward.

Joseph's difficulty sustaining fixation is related to his frequent head and body movements as well as a short attention span. These abrupt movements interfere with visual tracking skills, which are already inadequate because of poor grading of paired eye muscles for reciprocal action. Joseph has gained some skill, however, in "fixing" with his eyes on certain targets while his own head and body are moving (compensatory eye movements).

Gaze shifts within the same focal length are perfected developmentally earlier than shifts between different focal lengths. Joseph, however, achieves more accuracy with the latter, which do not require head movement. He shifts laterally with eyes and head together rather than eyes separate from the head, and therefore is prone to lose his place while reading and writing, especially while copying.

General recommendations: Joseph's visual impairment, which meets the definition for legal blindness in most states, indicates his need for orientation and mobility training. Functionally appropriate adaptations to static aspects of his condition should include classroom positioning for increased stability and to keep his postural alignment as symmetrical as possible. The positioning should allow necessary head turns and other compensations for field deficits not entirely corrected by the prisms.

Developmentally targeted interventions may include structured procedures to increase peripheral awareness to objects without sound or movement in both near and far space, and socially motivating activities to increase duration of fixations, to improve visual tracking to the right, and to provide practice scanning and identifying three or more targets in near, middle, and far space.

Re-evaluation is recommended in one year.

Signature

References

Barker-Griffith, A. 1986. Personal communication.

McLaurin, J. R. 1989. Personal communication.

Chapter Nine
Melinda: Assessment and Management

Date: June 25, 1986

To: Whom It May Concern

Re: Occupational Therapy Evaluation for Melinda Yardley

This 13½-year-old female with a diagnosis of cerebral palsy was evaluated with the Erhardt Developmental Vision Assessment (EDVA), which measures the motor components of vision, both reflexive visual patterns and voluntary eye movements of localization, fixation, ocular pursuit, and gaze shift. Melinda's eye muscles, both involuntary and voluntary, have been affected by cerebral palsy, which is defined as a condition in which damage has occurred to areas of the brain that control the motor system.

At the time the EDVA was administered, the most recent ophthalmology report stated that Melinda demonstrates Snellen acuities of 20/30+ O.D. (right eye) and 20/30- O.S. (left eye), and an alternating esotropia (inward eye turn) (Colliton 1986). Subsequent optometric findings included a retinoscopy report of +0.25 O.D. and +0.50 -.050 x 90 O.S., indicating a mild hyperopia and slight astigmatism in the left eye. Visual acuity at a distance was 20/25 O.U. (both eyes) and near was 20/30 O.D. and 20/60 O.S. Melinda's alternating esotropia (more at near point than distance) was confirmed by the Hirschberg and cover/uncover tests. Unable to achieve fusion at any time, she showed a preference for right eye fixation at near (Andrist 1988).

Although individuals in the normal population can easily accommodate Melinda's degree of mild hyperopia and slight astigmatism, children with cerebral palsy are often unable to *sustain* focus, especially at the near point required for efficient and comfortable reading and writing (Suchoff and Petito 1986).

Consultation with Melinda's optometrist included discussion of the optometric findings and those of the EDVA, analysis of functional implications, and consensual recommendations for management. Corrective lenses then prescribed were light amber (for glare reduction) with bifocals: sphere (no prescription for distance) and a +1.25 add for near (Andrist 1988).

A brief summary of the EDVA results will be presented, including the relationship of specific visual findings to the total motor action system, and implications for function in the school, home, and community environments. Recommendations for a management program integrated with Melinda's individualized education plan (IEP) will include functionally appropriate adaptations and developmentally targeted interventions.

Melinda's present educational performance levels show a two- to five-year delay, qualifying her for special services including a teacher certified in educationally mentally handicapped, one-to-one instruction by a management aide in all regular education classes, counseling, adaptive physical education, and occupational and physical therapy. New objectives written into her IEP at the beginning of the next school year will be related to daily living skills and careers, as well as her present needs of communication, social skills, math, and adaptive physical education, and will reflect the transition from academic to functional domains.

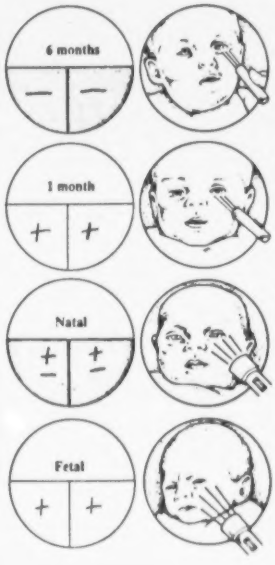
Section 1. Primarily Involuntary Visual Patterns (Reflexive)

1. a. PUPILLARY REACTIONS

Stimuli: Penlight (**weak** light) and Flashlight (**strong** light) directed into one eye within 12" in dimly lit room

Functional Implications: Tests rapidity of environmental adaptation since light is the first activation of the visual system

Developmental Levels		Pattern Components		Pattern Components	
Right	Left	R	L	R	L
		Eye		Eye	



Direct Light Reflex

- Pupil constricts quickly to **weak** light directed into eye
- Pupil dilates quickly when **weak** light is removed from eye
- Pupil constricts slowly to **weak** light directed into eye
- Pupil dilates slowly when **weak** light is removed from eye
- Pupil constricts quickly to **strong** light directed into eye
- Pupil dilates quickly when **strong** light is removed from eye

Late Stage (8-9 months)

- Pupil constricts slowly to **strong** light directed into eye
- Pupil dilates slowly when **strong** light is removed from eye

Early Stage (6-7 months)

- No pupil constriction to **weak** light directed into eye
- No pupil constriction to **strong** light directed into eye

Consensual Light Reflex
(stimulation of one pupil results in equal constriction of both)

- Pupil constricts quickly and equally to **weak** light directed into **other** eye
- Pupil dilates quickly and equally when **weak** light is removed from **other** eye
- Pupil constricts slowly and equally to **weak** light directed into **other** eye
- Pupil dilates slowly and equally when **weak** light is removed from **other** eye
- Pupil constricts quickly and equally to **strong** light directed into **other** eye
- Pupil dilates quickly and equally when **strong** light is removed from **other** eye

Late Stage (8-9 months)

- Pupil constricts slowly and equally to **strong** light directed into **other** eye
- Pupil dilates slowly and equally when **strong** light is removed from **other** eye

Early Stage (6-7 months)

- No pupil constriction to **weak** light directed into **other** eye
- No pupil constriction to **strong** light directed into **other** eye

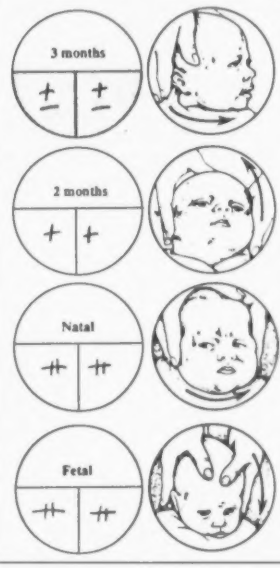
1.b. DOLL'S EYE RESPONSES

Stimuli: Passive movement of head against body

Functional Implications: Prepares for voluntary separation of eyes from head
Integrated when eyes and head move together voluntarily

Eyes should not be fixating on a target during the rapid passive head-turning

Developmental Levels		Pattern Components		Pattern Components	
Right	Left	R	L	R	L
		Direction		Eye	



Head Rotation

- Eyes move in same direction as head rotation: Integrated
- Delayed or inconsistent eye movements in same direction as head **rotation**: Beginning integration
- Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **rotation** during first 10 days, gradually decreasing

Mid Stage (7-8 months)

- Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **rotation**

Head Flexion/Extension

- Eyes move in same direction as head **flexion**: Integrated
- Eyes move in same direction as head **extension**: Integrated
- Delayed or inconsistent eye movements in same direction as head **flexion**: Beginning integration
- Delayed or inconsistent eye movements in same direction as head **extension**: Beginning integration
- Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **flexion** during first 10 days, gradually decreasing
- Strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **extension** during first 10 days, gradually decreasing

Mid Stage (7-8 months)

- Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **flexion**
- Slight apparent countertorsion of eyes (actually lagging behind) in opposite direction of head **extension**

Assessment Report

SECTION 1. Primarily Involuntary Visual Patterns (Reflexive)

1.a. Pupillary Reactions

Clinical observations: Pupils constrict quickly to strong light, but inconsistently to weak light; sluggish constriction to strong or weak light when directed into other pupil (consensual reflex)

Summary and implications for function: Pupillary reactions are not consistent, possibly correlated with Melinda's photophobia (light sensitivity).

General goal: Make environmental adaptations (amber lenses)

1.b. Doll's Eye Responses

Clinical observations: Integration of response (eyes move with head) during head extension and rotation to the right, but eyes lag behind head flexion and rotation to the left

Summary and implications for function: Involuntary eye movements (eyes lagging behind when head turns to the left) interfere with rapid and accurate relocalization to the beginning of the next line during reading, especially when Melinda reads orally and her eyes, mouth, and head are in motion. Shifts of gaze from desk to board and back are also inaccurate and slow when voluntary control is contaminated by involuntary eye-head relationships. Thus, board work may be unsuccessful and frustrating.

General goal: Improve voluntary control to help integrate reflexive patterns

Model for Management of Visual-Motor Dysfunction (fig. 9-1)

Individualized Management Program

Communication Domain

Goal: To improve reading skills

Objective: Melinda will orally read sixth-grade-level words with 90% accuracy.

Visual Components: Pupillary reactions and doll's eye responses

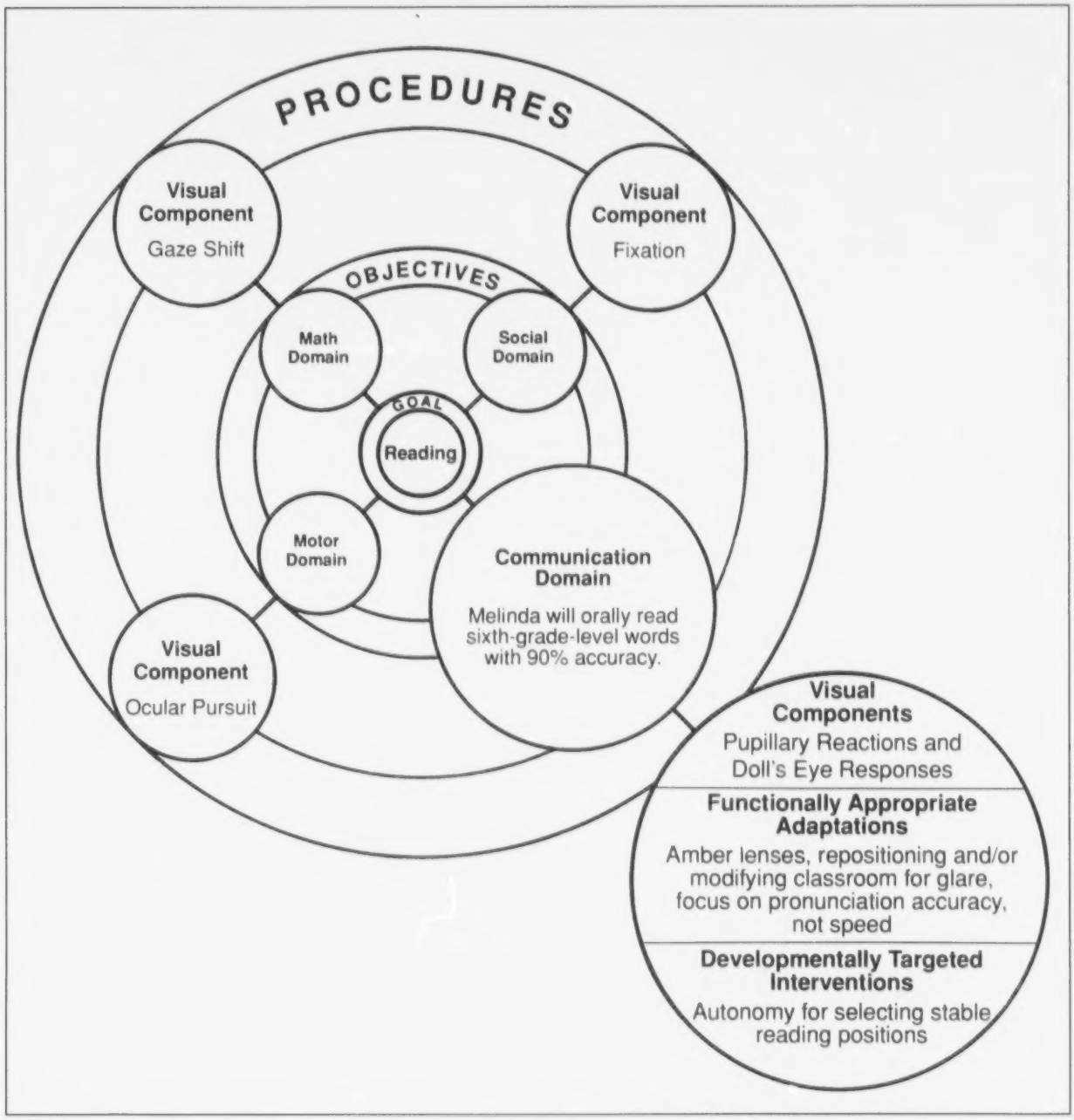


Fig. 9-1

Model for Management of Visual-Motor Dysfunction: Communication Domain

Visual Present Level of Function: Pupil constriction is inconsistent, being somewhat sluggish at times. This may or may not be related to Melinda's photophobia.

Melinda's reading posture is affected by delayed integration of the doll's eye response and her head position of asymmetrical extension, a stereotypic pattern used for stability when head control was imperfect during early development and retained for functional use. Involuntary eye movements (eyes lagging behind when head turns to the left) interfere with rapid and accurate relocalization to the beginning of the next line, especially when Melinda reads orally and her eyes, mouth, and head are all moving. Observation reveals that Melinda reads best with her chin resting on one or both hands, stabilizing her head (fig. 9-2). Without arm support, she stabilizes her head in an asymmetrical extension position, with eyes looking downward (fig. 9-3). When asked to tilt her head downward as she reads, she blinks during scanning movements, evidence of imperfect ocular control during gaze shifts (figs. 9-4, 9-5, 9-6).

Fig. 9-2

Fig. 9-3

Fig. 9-4

Fig. 9-5

Fig. 9-6

Visual Procedures

Functionally Appropriate Adaptations: During all classroom work, especially reading, Melinda may be adversely affected by bright sunlight, fluorescent lights, large areas of light from windows, or glare from chalkboards or white surfaces. She may not be aware of these problems nor able to express them, so staff may need to modify the environment or her position in the classroom to elicit optimal function. Amber lenses may also be helpful outdoors (for example, when reading a bus schedule) as well as in the classroom.

During oral reading, speed requirements may increase inaccuracy because of Melinda's difficulty in overcoming the effects of involuntary movements. Measurement of pronunciation accuracy is more appropriate than measurement of speed.

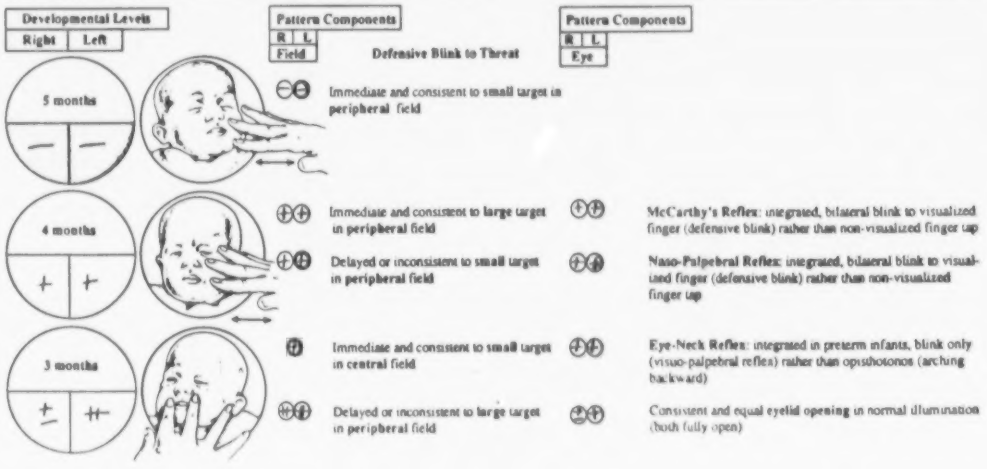
Developmentally Targeted Intervention: Inconsistent pupillary reactions are unlikely to improve at Melinda's age. Reflexive patterns are best integrated by improving voluntary eye muscle control.

Since reading is now an integrated functional skill, no attempt should be made to alter her method or position. She should be allowed to find postural stability in whatever way possible in any given environment (fig. 9-7).

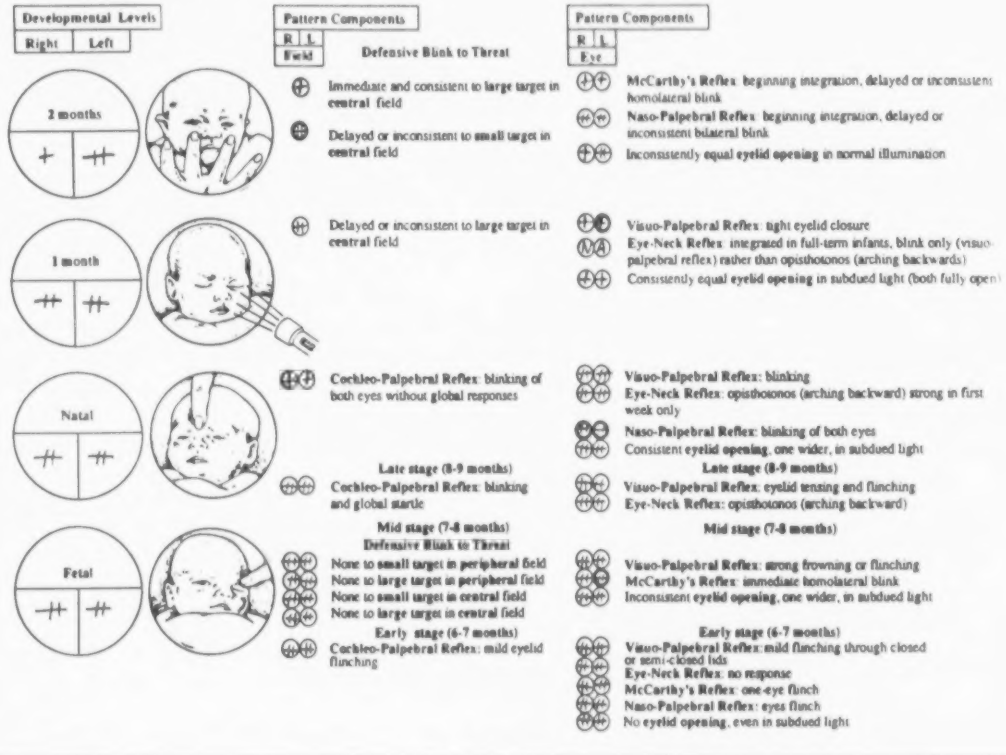
Fig. 9-7

I.c. EYELID REFLEXES

	Stimuli	Functional Implications
Defensive Blink to Threat	Rapid approach and removal of visualized target (Small: spread fingers; Large: test booklet)	Protects eyes from tactile assault
McCarthy's Reflex	Light non-visualized tap above one eyebrow (supraorbital area)	Activates unilateral eyelid function
Naso-Palpebral Reflex	Light non-visualized tap on bridge of nose	Activates bilateral eyelid function
Eye-Neck Reflex	Bright light in eyes, head unsupported (flashlight)	Primitive survival reaction
Visuo-Palpebral Reflex	Bright light in eyes (flashlight)	Protects eye from excessive light
Cochleo-Palpebral Reflex	Sharp noise (hand clap)	Protects eye from certain non-visual stimuli


Developmental Levels
Right
Left
Pattern Components
R
L
Field
Defensive Blink to Threat
Pattern Components
R
L
Eye
5 months
Immediate and consistent to small target in peripheral field
4 months
Immediate and consistent to large target in peripheral field
Delayed or inconsistent to small target in peripheral field
McCarthy's Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap
Naso-Palpebral Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap
3 months
Immediate and consistent to small target in central field
Eye-Neck Reflex: integrated in preterm infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backward)
Delayed or inconsistent to large target in peripheral field
Consistent and equal eyelid opening in normal illumination (both fully open)

I. c. EYELID REFLEXES


Developmental Levels
Right
Left
Pattern Components
R
L
Field
Defensive Blink to Threat
Pattern Components
R
L
Eye
2 months
Immediate and consistent to large target in central field
Delayed or inconsistent to small target in central field
McCarthy's Reflex: beginning integration, delayed or inconsistent homolateral blink
Naso-Palpebral Reflex: beginning integration, delayed or inconsistent bilateral blink
Inconsistently equal eyelid opening in normal illumination
1 month
Delayed or inconsistent to large target in central field
Visuo-Palpebral Reflex: tight eyelid closure
Eye-Neck Reflex: integrated in full-term infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backwards)
Consistently equal eyelid opening in subdued light (both fully open)
Natal
Cochleo-Palpebral Reflex: blinking of both eyes without global responses
Visuo-Palpebral Reflex: blinking
Eye-Neck Reflex: opisthotonos (arching backward) strong in first week only
Naso-Palpebral Reflex: blinking of both eyes
Consistent eyelid opening, one wider, in subdued light
Late stage (8-9 months)
Cochleo-Palpebral Reflex: blinking and global startle
Late stage (8-9 months)
Visuo-Palpebral Reflex: eyelid tensing and flinching
Eye-Neck Reflex: opisthotonos (arching backward)
Mid stage (7-8 months)
Fetal
Mid stage (7-8 months)
Defensive Blink to Threat
None to small target in peripheral field
None to large target in peripheral field
None to small target in central field
None to large target in central field
Visuo-Palpebral Reflex: strong frowning or flinching
McCarthy's Reflex: immediate homolateral blink
Inconsistent eyelid opening, one wider, in subdued light
Early stage (6-7 months)
Cochleo-Palpebral Reflex: mild eyelid flinching
Early stage (6-7 months)
Visuo-Palpebral Reflex: mild flinching through closed or semi-closed lids
Eye-Neck Reflex: no response
McCarthy's Reflex: one-eye flinch
Naso-Palpebral Reflex: eyes flinch
No eyelid opening, even in subdued light

Assessment Report

1.c. Eyelid Reflexes

Clinical observations: Consistent and immediate defensive blink to threat in central visual field; inconsistent defensive blink in peripheral fields;

Equal eyelid opening only in subdued light, with right eye frequently partially closed in normal illumination (fig. 9-8)

Fig. 9-8

Summary and implications for function: The eyelid blink helps protect the eye from foreign substances. Unequal eyelid opening may be related to muscle asymmetries and efforts to focus as well as pupillary reactions. Delayed automatic components of the visual-motor system indicate less efficient central nervous system function. However, for functional activities such as catching a ball, maturity is demonstrated by the ability to override the defensive blink.

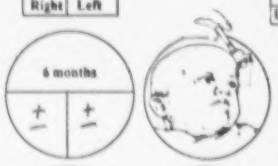
Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)

2. a. LOCALIZATION (VISUAL APPROACH)

Target Size	Focal Lengths	Stimuli
Large: bigger than examiner's hand	Near space: 3-12"	Light
Small: size of hand or smaller	Middle space: 1-6'	Sound
Tiny: pellet size	Far space: 6-20'	Faces
	Distant space: 20'-infinity	Contour
		Movement

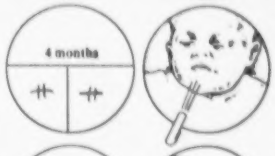
Developmental Levels — Right | Left

Pattern Components — R | L — Direction

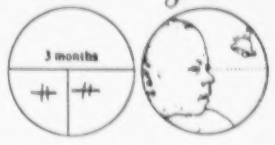


Eyes localize, then **hand** approaches and contacts tiny target eyes leave target when hand contacts
Eyes move independently from stabilized **head** to localize target needs head externally stabilized
Localizes non-vocalizing **face** in far space
Localizes large **target** by **contour/pattern** in **far** space
Adjusts **body** position to localize target more easily
Turns to side, then up, to localize non-visualized **sound** above ear
Turns in arc movement to localize non-visualized **sound** below ear

Eyes and **hand pursue** lost small target outside visual field
Eyes localize tiny **target** in **near** space, without **hand** approach
Eyes begin to move independently from stabilized **head** to localize target
Localizes vocalizing **face** in **far** space
Localizes large **moving** target in **far** space
Localizes small **target** by **contour/pattern** in **middle** space
Turns to side, then down, to localize non-visualized **sound** below ear



Eyes localize and **hand** grasps small target in near space
Eyes, not **hand**, pursue lost small target outside of visual field
Smiles at own **face** in mirror spontaneously or when tapped
Localizes large **target** by **contour/pattern** in **middle** space
From side, From above, From below: Localizes **penlight** moving slowly into peripheral field in an arc 12° away at 90° from central fixation point (tested in subdued light)



Eyes and **head** move together consistently to localize target
Eyes regard own **hand** spontaneously
Prompt regard to target presented **centrally** (in body midline)
Eyes localize and **hand** approaches, contacting small target in near space
Eyes glance briefly at target in own moving **hand**
Localizes large **moving** target in **middle** space
Eyes turn to target with sound properties placed in own hand
Turns toward side of non-visualized **sound** 18° from ear
Localizes non-vocalizing face in middle space

---

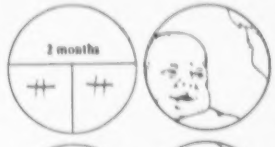
2. a. LOCALIZATION (VISUAL APPROACH)

Testing localization to diffuse light. Subject is observed during slow rotation away from light, for head derotation toward light.

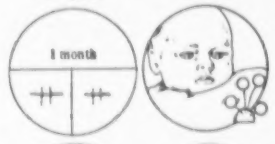
Testing localization of penlight moving into peripheral field from each side and above. Examiner stands behind subject who is fixating on another target at central fixation point. To test from below: Subject reclines as target is brought upward from feet.

Developmental Levels — Right | Left

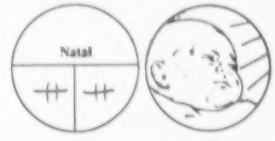
Pattern Components — R | L — Direction



Eyes glance at own moving **hand/fingers**
Delayed regard to target presented **centrally** from below (viewed at chest level)
Turns to target in **peripheral** surroundings
Localizes **penlight** moving slowly into peripheral field in an arc 12° away at 30° from central fixation point
Localizes small target with internal **movement** up to 3' away
Localizes large target with internal **movement** in **middle** space
Localizes non-vocalizing **face** in near space
Localizes vocalizing **face** in middle space
Turns toward general direction of non-visualized **sound** source



Eyes and **head** move together inconsistently during voluntary movements
Localizes diffuse **light** source
Localizes small target with internal **movement** up to 12° away
Brief glances at large target with internal **movement** in **middle** space
Brief regard of non-vocalizing **face** in near space
Localizes vocalizing face in near space



Random **eye** movements, not together with random **head** and **body** movements
Diffuse distractibility to target in **peripheral** surroundings
Turns toward large areas of **light**
Localizes small target with internal **movement** exactly 8° away

Late Stage (8-9 months)

Turns toward diffuse **light**
Faint interest in **peripheral** surroundings
Localizes focalized **light** (penlight) moving into peripheral field at central fixation point
Widens eyes and attends to pleasant non-visualized **sound** without head turning

Early Stage (6-7 months)

No response to visual target
No head-turning toward diffuse **light**
Involuntary **eyeball** movements in all directions, even under closed lids
Mild eyelid flinching to non-visualized **sound**
No head-turning toward focalized **light**

Assessment Report

SECTION 2. Primarily Voluntary Eye Movements (Cognitively Directed)

2.a. Localization (Visual Approach)

Clinical observations: Eyes move quickly and accurately to all targets (with properties of light, sound, movement, pattern, etc.) in all visual fields and all focal lengths.

Summary and implications for function: Prompt and accurate localization movements are a strength, but their almost obligatory nature (the need to respond to all stimuli) can be a contributing factor to distractibility and attention problems in the classroom. Significant effort must then be made to maintain concentration on a task. Obsessive interest in certain topics appears to be one way Melinda tries to screen out excessive sensory input.

General goal: Improve ability to selectively screen environmental stimuli

2. b. FIXATION (VISUAL GRASP)

Modes of Visual Processing
Ambient: passive stare, with awareness of surroundings Focal: active focus on target, excluding surroundings

Approximate Functional Focal Lengths		
Near Space: 3-12"	Middle Space: 1-6'	Far Space: 6-20'

Developmental Levels: Right | Left

Pattern Components: R | L — Field (Both Eyes)

Pattern Components: R | L — Eye (Other Occluded)

6 months

Intense **focal** fixation with visual responses, global suppressed — blinks
Inspects own **face** in mirror intently
Eyes fixate on tiny target while **hand** approaches and contacts — localizes, looks away, then hands gropes for target
Fixates at **focal lengths**: 3" - 20'

L eye better than R eye

5 months

Frequent small lateral excursions
Maintains **focal** fixation with more visual than global responses
Maintains fixation on stationary target in competition with **moving** one — possible only with requested concentration, squints with the effort
Intermittent regard of own **face** in mirror
Eyes fixate on tiny target without **hand** approach
Fixates on **focal lengths**: 3" - 6'

4 months

stabilizes head by resting chin on hands when searching for space
Efficient **ambient** inspection of surroundings in middle and far space
Eyes maintain fixation on small target in **hand** — brings target very close
Prolonged, selective **focal** fixation with multiple global responses
Uses **ambient** stare/ fixation on surroundings to rest from intense focal fixation
Consistent **binocular fixation** — difficulty in middle space, head down, eyes up
Eyes fixate recurrently and with delay on tiny target without **hand** approach
Fixates at **focal lengths**: 4" - 9'

3 months

Maintains fixation on non-vocalizing **face** for 10 seconds
Crude **ambient** inspection of surroundings in middle and far space
Direct, discriminative **focal** fixation on target in midline
Inconsistent **binocular fixation**
Eyes fixate briefly on small target placed in own **hand**
Prolonged fixation on target with rhythmical **movement**
Maintains fixation on stationary target unless distracted by moving one
Fixates at **focal lengths**: 5" - 3'

L > R

---

2. b. FIXATION (VISUAL GRASP)

Fixation Criteria (Global responses mature to visual only)	
Global Eyes and mouth open, increased or decreased respiration, muscle tone, or body activity	**Visual** Pupils constricted, eyes round rather than oval, upper eyelids tensed and raised, eyes relatively immobile

Developmental Levels: Right | Left

Pattern Components: R | L — Field (Both Eyes)

Pattern Components: R | L — Eye (Other Occluded)

2 months

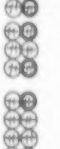
Direct discriminating **focal** fixation on target at the side of midline
Maintains fixation on vocalizing **face** for 10 seconds
Beginning **binocular fixation** with blinking and overconvergence
Eyes regard **hand** in ATNR position (head facing extended arm, other flexed)
Fixates longer on **black and white** bull's eye **pattern** than stripes
Fixates at **focal lengths**: 6" - 2'

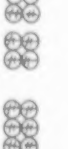
1 month

Brief **focal** fixation on target at the side of midline
Fleeting regard of non-vocalizing **face**
Brief fixation on vocalizing **face** for 2-3 seconds
Defined **monocular fixation**: active eye fixates on target, other shifts nasally
Bi-ocular fixation (alternating monocular): fixation alternates rapidly between both eyes, which shift with head in rhythmical lateral excursions
Roving eyes become relatively immobile, with **ambient** stare at surroundings
Fixates longer on black and white stripes than bull's eye **pattern**
Fixates at **focal lengths**: 7" - 12"

Natal

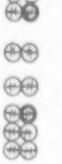
Tries to achieve **focal** fixation on target at side of midline, with some global responses
Vague, intermittent, **ambient** regard of surroundings
Crude **monocular fixation**: active eye aligns, tries to immobilize and fixate momentarily on target while inactive eye closes or deviates nasally or temporally
Regards target with internal **movement** placed in line of vision
Maintains **ambient** gaze toward diffuse light by turning head when slowly rotated away
Fixates longer on **black and white pattern** than on target without pattern/contrast
Fixates at **focal length**: 8"





Fetal

Late stage (8-9 months)
Immobilizes eyes briefly in pseudo-fixation (diffuse, passive, **ambient**)
Mid stage (7-8 months)
Briefly alert to target with **movement** properties (agitated or dangling)
Early stage (6-7 months)
No **focal** fixation
No immobilization of eyes in **ambient** stare at surroundings
No **ambient** gaze toward light



Assessment Report

2.b. Fixation (Visual Grasp)

Clinical observations: Efficient ambient inspection of surroundings;

Monocular fixation (one eye used at a time, rather than both, thus no fusion); right eye preferred in near space with alternating monocular fixation in far space;

Prolonged focal fixation on certain targets of interest in all focal lengths;

Intermittent regard of nonvocalizing faces and own image in mirror;

Unable to maintain fixation on a stationary target in competition with moving ones;

Difficulty keeping eyes relatively immobile during global body movements, especially in standing, when continual stepping movements rather than more appropriate balance reactions are used as compensations for poor balance

Summary and implications for function: Short fixations interfere with discrimination of academic materials and general attending skills for future vocational tasks. Social concerns require thorough inspection of self in a mirror for grooming, as well as eye contact during conversational interactions.

General goal: Increase duration of fixations

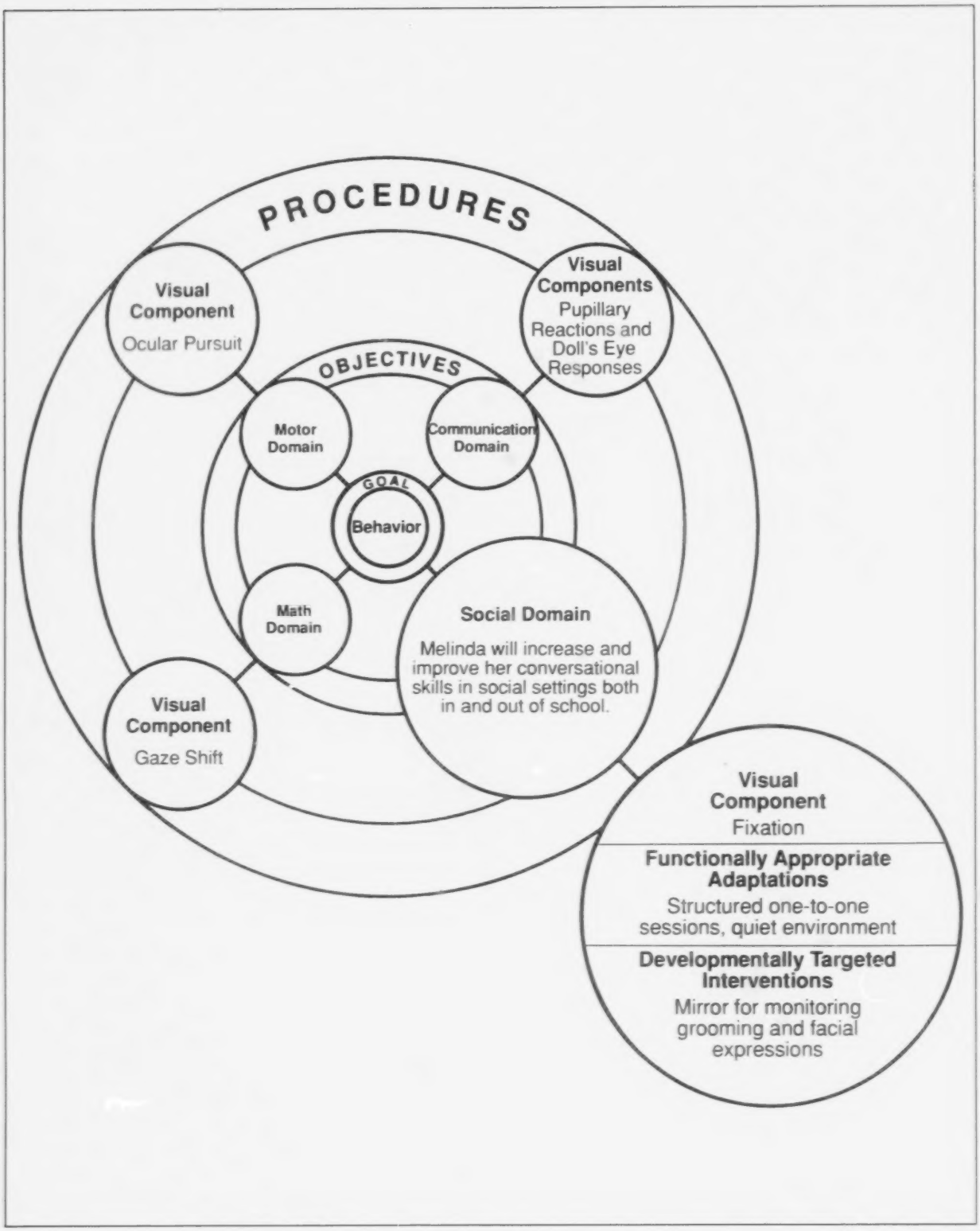


Fig. 9-9

Model for Management of Visual-Motor Dysfunction: Social Domain

Model for Management of Visual-Motor Dysfunction (fig. 9-9)

Individualized Management Program

Social Domain

Goal: To increase socially appropriate behaviors

Objective: Melinda will increase and improve her conversational skills in social settings both in and out of school.

Visual Component: Fixation

Visual Present Level of Function: Melinda does not maintain fixation on her own face in a mirror, which can relate to eye contact with others' faces, an important social skill during conversation. She is not willing to check her personal appearance in a mirror for hair neatness, clothing adjustments, and skin cleanliness, especially after meals. She does not have binocular fixation (both eyes working together) and uses the right eye more often than the left, especially in near space, alternating right and left more equally in middle and far space. Although her visual acuity is slightly better in the right than the left, her muscle control for fixation as well as movement is sometimes better in the left than the right eye, especially at the end of the day, when the right eye may be fatigued. Constant eye-head-body movements interfere with fixation on near targets, and she has difficulty maintaining fixation on a stationary target when distracted by a moving target. Also, her emotional control parallels her motor control of her eyes as well as her entire body. Her difficulty grading movement is reflected in poor grading of emotional responses, resulting in noncompliance, inappropriate laughter, overreactions, anger, and/or withdrawal.

Visual Procedures

Functionally Appropriate Adaptations: For optimal academic performance, Melinda needs one-to-one attention and a quiet environment in order to concentrate, especially when taking tests. She can better control her social/emotional responses, which are related to her physical state, if her environment is structured to reduce the amount of sensory input.

Developmentally Targeted Interventions: Mirror work could improve duration of fixation and general attending skills. Melinda could be encouraged to spend time grooming her hair and applying makeup at a mirror (normal teen-age activity). Dual mirror activities with Melinda and her management aide facing a mirror side by side could consist of taking turns checking each other's appearance, for example, finding hair needing combing, a twisted collar, or food on the chin (fig. 9-10). The visual feedback will also increase her awareness of how her expressions and actions appear to others.

Fig. 9-10

2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

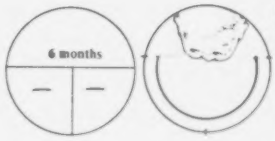
Approximate Functional Focal Lengths	
Near Space: 3 - 12"	Far Space: 6 - 20'
Middle Space: 1 - 6'	Distant Space: 20' - infinity

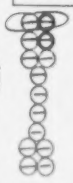
Compensatory Eye Movements: Eyes remain on stationary target during active head movements

Developmental Levels	
Right	Left

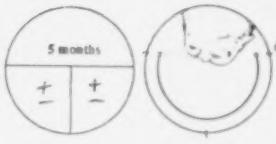
Pattern Components: R | L — Direction (Both Eyes)

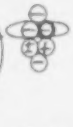
Pattern Components: R | L — Eye (Other Occluded)



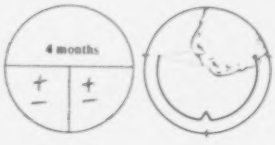


Eyes move independently from **head** to extreme right/left fields **while tracking**
Tracks target **horizontally 180°** smoothly at all speeds, **focal length 3" - infinity**
Tracks to **circular** direction smoothly at all speeds and focal lengths
Tracks **vertically upward** smoothly at all speeds and focal lengths
Tracks **vertically downward** smoothly at all speeds and focal lengths
Smooth **convergence** from far to near space
Smooth **divergence** from near to far space
Tracks **diagonally upward** with midline pause to refixate
Tracks **diagonally downward** with midline pause to refixate

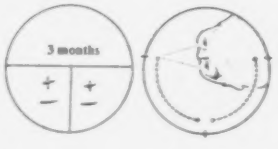


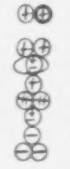


Eyes begin to move independently from **head** to limited upper/lower fields
Tracks target **horizontally 180°** without midline jerk, **focal length 3" - 6'**
Continuous **diagonal** tracking **downward** with some jerky movements
Smooth **convergence** from far to middle space
(L) eye appears to track better than (R)
Tracking better toward the (L) than toward the (R)



Eyes begin to move independently from **head** to limited right/left fields
Tracks target **horizontally 180°** with midline jerk, **focal length 4" - 5'**
Continuous **circular** tracking with some jerky movements — poor in lower field
Continuous **vertical** tracking **downward** with some jerky movements
Continuous **diagonal** tracking **upward** with some jerky movements
Smooth **divergence** from middle to far space





Tracks target **horizontally 180°** continuously, overshooting, with midline pause and re-localization, **focal length 5" - 3'**
Tracks, lingers, and visually searches for target at point of disappearance
Continuous **vertical** tracking **upward** with some jerky movements
Beginning **vertical** tracking **downward**, in series of jerky movements, losing and regaining target
Beginning **diagonal** tracking **upward**, in series of jerky movements, losing and regaining target
Continuous **convergence** with some jerky movements from middle to near space
Continuous **divergence** with some jerky movements from near to middle space
Compensatory Eye Movements: eyes remain on stationary target consistently during rapid and extensive voluntary head movements

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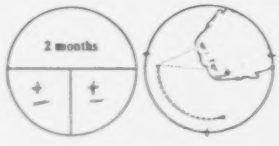
2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

Tracking Movements	Vergence Movements
Eyes remain on target during horizontal, vertical, circular, and diagonal movements	Eyes remain on target during convergence and divergence in all focal lengths

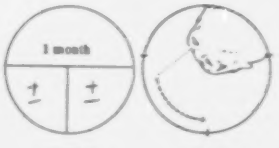
Developmental Levels	
Right	Left

Pattern Components: R | L — Direction (Both Eyes)

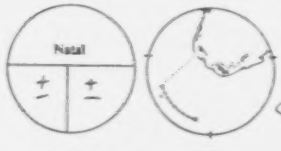
Pattern Components: R | L — Eye (Other Occluded)



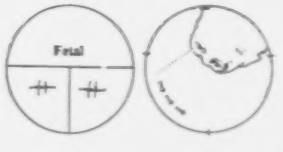
Tracks target **horizontally 90°** slightly past midline, jerky movements, poor regulation of eye speed to target speed, **focal length 6" - 2'**
Beginning **circular** tracking in series of jerky movements, losing and regaining target in lower field
Beginning **vertical** tracking **upward** in series of jerky movements losing and regaining target
Beginning **convergence** with short jerks, blinking, and overconvergence within near space
Beginning **divergence** with short jerks, blinking, and overdivergence within near space
Compensatory Eye Movements: eyes remain on stationary target inconsistently during rapid and extensive voluntary head movements
Follows target longer during **approach** than **retreat**



Tracks target **horizontally 60°** from periphery to midline and back to side, jerky movements, **focal length 7 - 12"**
Follows target equal distance during **approach** and retreat
Compensatory Eye Movements: eyes remain on stationary target during moderate speed and excursions of voluntary head movements



Eyes and **head** move together during tracking
Eyes and **head** move randomly in short lateral excursions
Tracks target **horizontally 45°** in peripheral field, in series of jerky movements, losing target frequently, difficulty regaining, **focal length 8"**
Follows target longer during **retreat** than **approach**, between 8 and 12"
Compensatory Eye Movements: eyes remain on stationary target during very slow voluntary head movements in limited range



Late Stage (8-9 months)
Tracks slowly moving target with internal movement horizontally 30° in peripheral field in near space, constantly losing target, able to regain if target pauses
Mid Stage (7-8 months)
Momentary afterpursuit of slowly moving target with internal movement (fluttering fingers)
Early Stage (6-7 months)
Eyes move without purpose, separate from **head**, even under closed lids
No response to visual target

Assessment Report

2.c. Ocular Pursuits (Visual Manipulation)

Clinical observations: Although the left eye tracks horizontally through 180 degrees better than the right eye (toward the left better than toward the right), tracking skills in all directions are deficient, with frequent visual loss of target, especially at midline and lower fields, and excessive blinking;

The right eye is beginning to move separately from the head, but the left still moves with it (tested with each eye occluded);

Great difficulty in keeping eyes on a stationary target during rotational head movements;

No true convergence possible because eyes were not used together

Summary and implications for function: Visual input and output cannot be consistent and accurate when an individual's body is in constant motion and without stable orientation in space.

General goal: Improve ocular pursuit in horizontal and vertical directions, eyes separate from head, and compensatory eye movements (keeping eyes on stationary target during head and body motion)

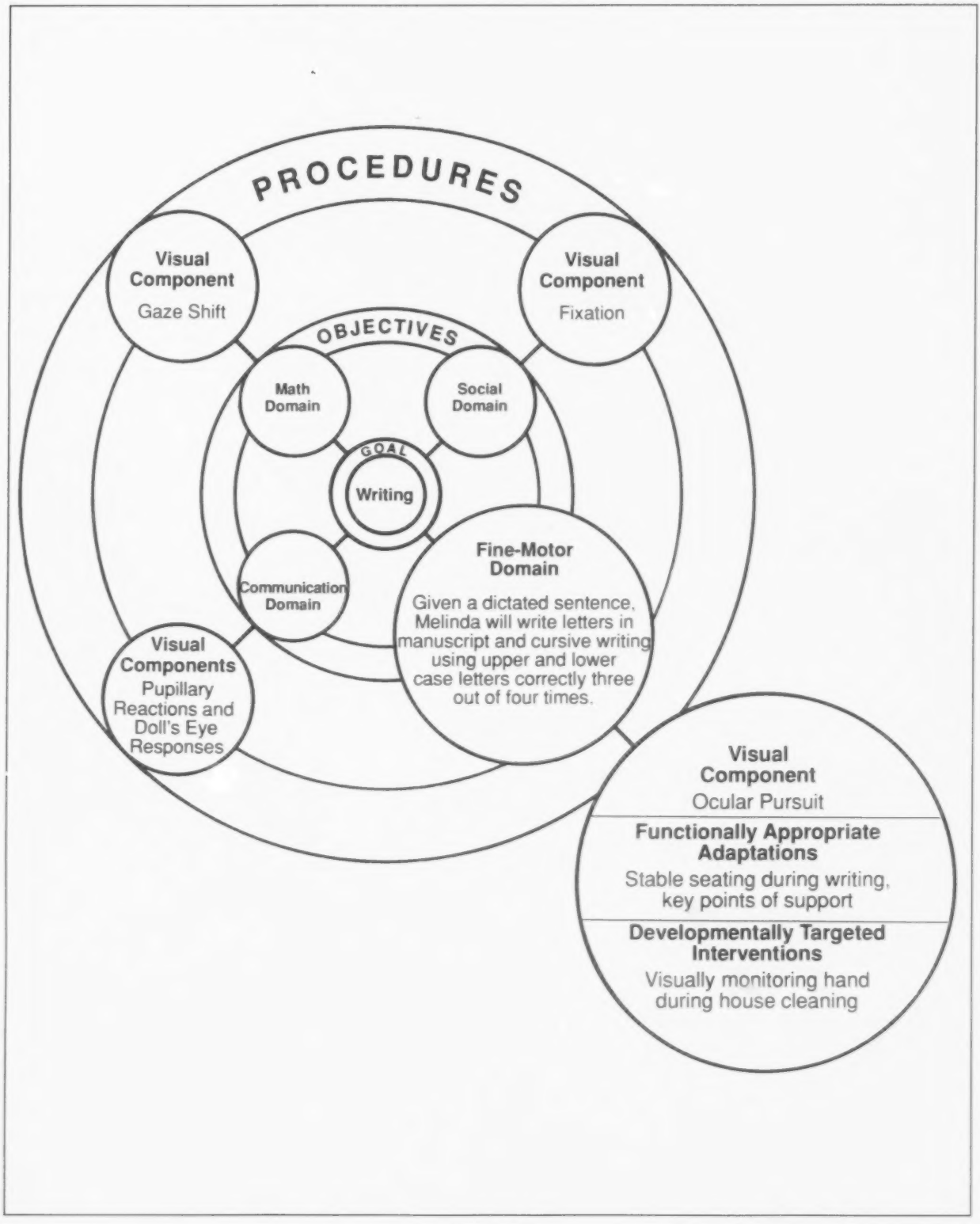


Fig. 9-11

Model for Management of Visual-Motor Dysfunction: Fine-Motor Domain

Model for Management of Visual-Motor Dysfunction (fig. 9-11)

Individualized Management Program

Fine-Motor Domain

Goal: To improve writing skills

Objective: Given a dictated sentence, Melinda will write letters in manuscript and cursive writing using upper and lower case letters correctly three out of four times.

Visual Component: Ocular pursuit

Visual Present Level of Function: Horizontal tracking (eyes following the moving hand or pencil) is irregular, with frequent visual loss of target, especially at midline and in lower visual fields, with excessive blinking. The eyes do not work together smoothly, with the left eye tending to move together with the head and the right eye moving separately from the head. Melinda does not always watch her moving hand.

Visual Procedures

Functionally Appropriate Adaptations: Efforts can be made to provide Melinda with optimal stable seating, hips at 90 degrees, feet flat on the floor, desk at appropriate height, and forearms totally supported during writing activities (fig. 9-12).

Developmentally Appropriate Interventions: Ocular pursuit and eyes watching moving hand can be improved during domestic activities such as dusting furniture and wiping kitchen counters after food preparation. Melinda's occupational therapist can emphasize the need for her to visually monitor her moving hand for efficient cleaning (fig. 9-13).

Fig. 9-12

Fig. 9-13

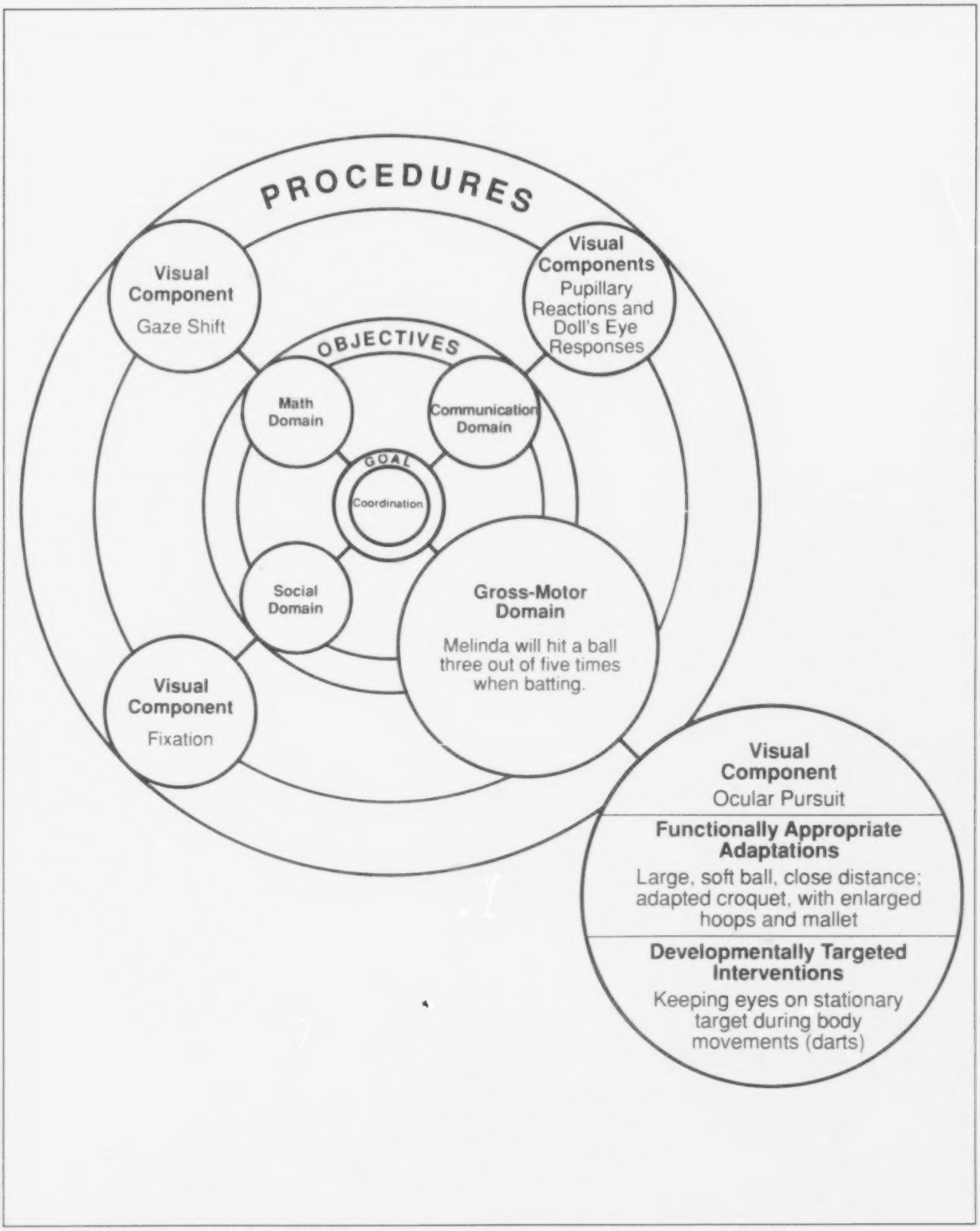


Fig. 9-14

Model for Management of Visual-Motor Dysfunction: Gross-Motor Domain

Model for Management of Visual-Motor Dysfunction (fig. 9-14)

Individualized Management Program

Gross-Motor Domain

Goal: To improve coordination

Objective: Melinda will hit a ball three out of five times when batting.

Visual Component: Ocular pursuit

Visual Present Level of Function: True convergence is not possible because Melinda's eyes are not used together (binocular fixation). Efforts to follow an approaching target show jerky movements, blinking, and loss of target. Performance within near and middle space (up to 6') is easier than within middle and far space (up to 20'). Constant head and body motions interfere with consistent visual input, especially since Melinda is not able to keep her eyes on a stationary target during head motion (compensatory eye movements).

Visual Procedures

Functionally Appropriate Adaptations: During batting activities in adaptive physical education class, Melinda may need to use a large, slow-moving foam ball and begin with the ball thrown from six feet away or closer.

Developmentally Targeted Interventions: Fixation on a target point (compensatory eye movements) to improve Melinda's orientation in space can be required during all physical therapy activities for flexibility, stability, strength, and graded control. Examples of activities include weight shifting in the forward-step position (left leg forward), side sitting on the right, pointer positions, slow motion transitions within standing/sitting/chair/floor, rolling sideways totally flexed and back to midline, and walking on an adapted balance beam 2 inches thick by 6 inches wide or wider, instead of the standard two by four. Visual tracking in all directions, especially in the lower quadrants, is recommended during weight bearing on extended arms when prone over bench.

For lifetime leisure activities, Melinda can practice keeping her eyes on a stationary object during arm and body movements by joining her grandfather in a game of adapted croquet, using the side of the mallet and enlarged hoops (fig. 9-15).

Fig. 9-15

2. d. GAZE SHIFT (VISUAL RELEASE)

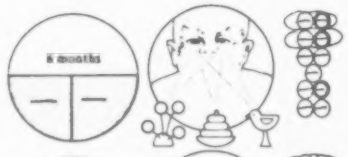
Developmental Levels	
Right	Left

Pattern Components
R | L
Direction

Functional Focal Lengths
Near space: 3 - 12"
Middle space: 1 - 6'
Far space: 6 - 20'
Distant space: 20' - infinity

Shift Gaze: eyes move from one target to another within same focal length or between different focal lengths

Alternate Glance: between 2 targets
Scanning: between 3 or more targets



Scans 3 or more targets within **all focal lengths** quickly and accurately
Eyes move independently from **head** to shift gaze
Alternates glance between 2 targets in **same focal length** within **far space** easily
Shifts gaze between targets **in near** and **far space** quickly and accurately
Shifts gaze within **and** between all focal lengths without **blinking**
Shifts gaze easily during adaptive interaction of **eye/hand/mouth**: regards target, grasps, mouths, withdraws, regards, manipulates, releases, resecures, etc.

Alternates glance between 2 targets in **same focal length** within **middle space** easily
Alternates glance between 2 targets in **same focal length** within **near space** easily
Shifts gaze between targets in **middle and far space** accurately
Shifts gaze between targets **in near and middle space** accurately eye extends head when shifting to middle space
Scans 3 or more targets in **middle space** quickly but inaccurately
Eyes begin to move independently from **head** to shift gaze
Shifts gaze between **near and far space** (releases fixation) during adaptive interaction of eye/hand/mouth (grasping, manipulating, mouthing target)

Conjugate Deviations: eyes consistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **far space** inaccurately
Scans 3 or more targets in **near space**, overshooting, re-localizing
Tenacious fixation **interferes with** smooth release (**alternate glance**) in **near space**
Shifts gaze between targets **in near and middle space** inaccurately
Shifts gaze between targets **in near** and **far space** with **blinking** and eye-rolling
Shifts gaze from **surroundings** to target in own **hand** after mouthing

Conjugate Deviations: eyes inconsistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **middle space** inaccurately
Begins to shift gaze between targets in near and middle space slowly, with difficulty
Eyes and **head** move together consistently during voluntary gaze shifts
Shifts gaze between own **hand** and target during approach
Alternates glance between target placed on surface and **hand** withdrawn
Shifts gaze consistently without **blinking** between targets in same focal length.

---

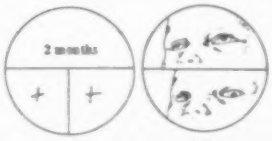
2. d. GAZE SHIFT (VISUAL RELEASE)

Conjugate Deviations: eyes move together in same direction at same time (yoked)

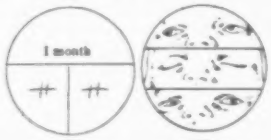
Components of Gaze Shift (Alternate Glance or Scanning)
1. Release of fixation on target
2. Re-localization on next target
3. Repeat

Developmental Levels	
Right	Left

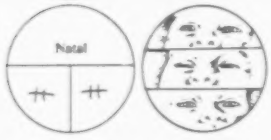
Pattern Components
R | L
Direction



Conjugate Deviations: eyes move voluntarily more than involuntarily (randomly)
Conjugate Deviations: eyes move separately during primarily voluntary gaze shifts
Shifts gaze in **same focal length** in **near space**, inaccurately, overshooting target
Shifts gaze from own **hand** to **surroundings** (releases fixation)
Shifts gaze consistently without **blinking** during involuntary gaze shifts
Shifts gaze inconsistently without **blinking** during voluntary gaze shifts (release of focal fixation)

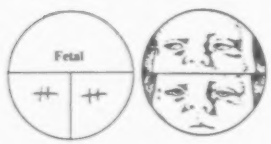


Conjugate Deviations: eyes move separately during beginning voluntary gaze shifts
Conjugate Deviations: eyes move together during primarily involuntary gaze shifts
Eyes and **head** move together inconsistently during beginning voluntary movements
Blinks consistently during release of ambient fixation (stare at surroundings)



Conjugate Deviations: eyes move together during involuntary gaze shifts
Eyes and **head** move together during random movements of both
Blinks inconsistently during release of ambient fixation (stare at surroundings)

Mid Stage (7-8 months)



No eye/**hand** interaction during eye movements
Random, sluggish **blinks** during eye movements
Involuntary gaze shifts between **different focal lengths**
Involuntary gaze shifts in **same focal length**

Early Stage (6-7 months)

Conjugate Deviations: eyes move co-jointly in all directions during involuntary movements even under closed lids
Eyes move independently from **head** during random movements of both

Assessment Report

2.d. Gaze Shift (Visual Release)

Clinical observations: Slow and inaccurate alternate glances and scanning of three or more targets in near, middle, and far space, especially to the right, with eyes unable to move separately from the head;

Difficult shifts from one focal length to another, with blinking and excessive head extension when shifting to middle or far space;

Smooth gaze shifts between own hand/target /surroundings during approach, grasp, and manipulation

Summary and implications for function: Copying information from one place to another is inefficient when the eyes can't move separately from the head and when excessive blinking reduces incoming visual information. Visual localization skills for finding small symbols within a printed page are excellent, but shifting gaze to relocalize to the exact place to write answers is difficult without perfect ocular muscle control and relates to future independent living tasks such as using a checkbook.

Shifting from one focal length to another such as from desk to chalkboard and back may be so slow and inaccurate, with frequent loss of place, that copying tasks may not be completed in the time allotted for the class.

General goal: Improve speed and accuracy of gaze shifts within same focal length and different focal lengths

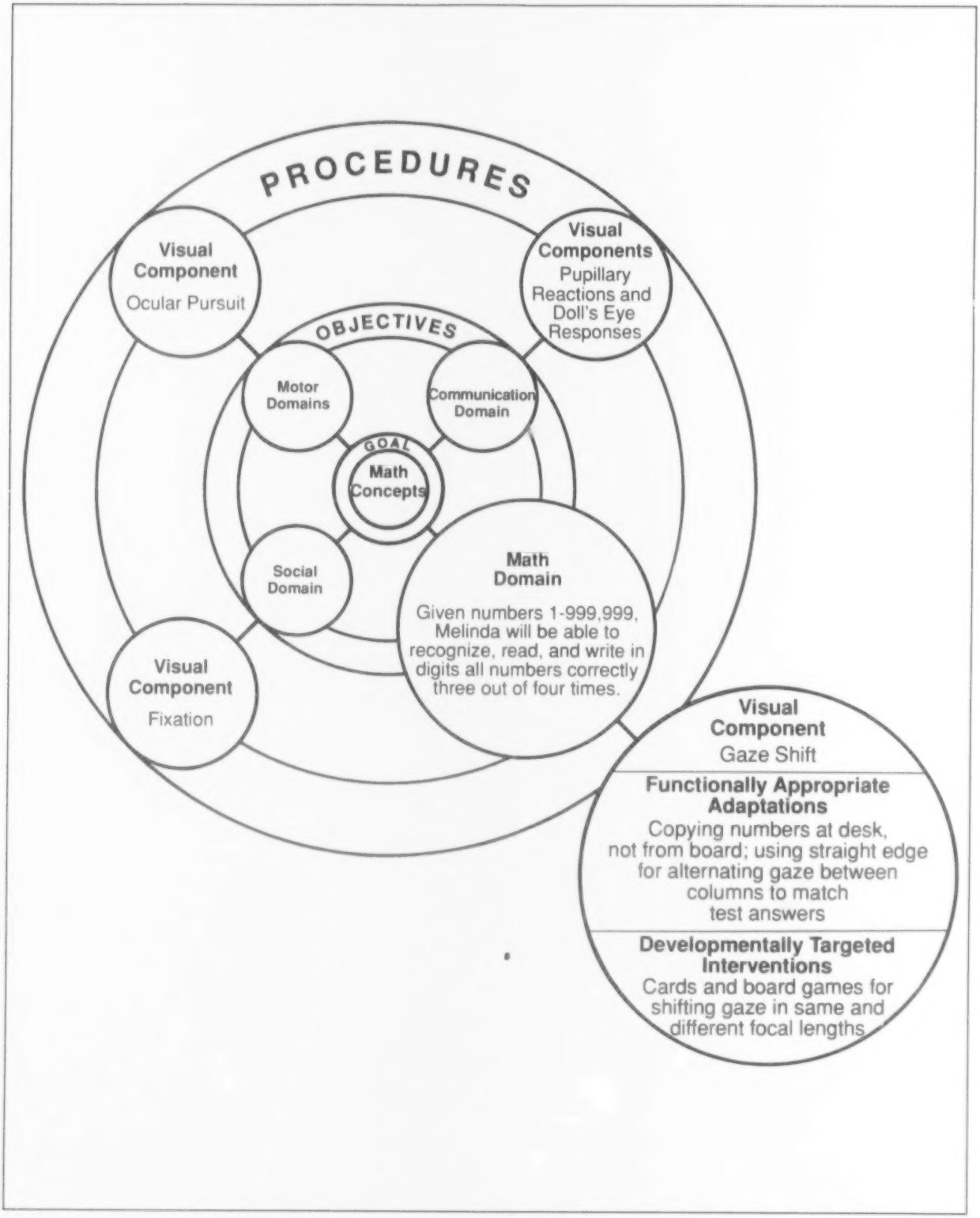

PROCEDURES
Visual Component
Ocular Pursuit
Visual Components
Pupillary Reactions and Doll's Eye Responses
OBJECTIVES
Motor Domains
Communication Domain
GOAL
Math Concepts
Social Domain
Math Domain
Given numbers 1-999,999, Melinda will be able to recognize, read, and write in digits all numbers correctly three out of four times.
Visual Component
Fixation
Visual Component
Gaze Shift
Functionally Appropriate Adaptations
Copying numbers at desk, not from board; using straight edge for alternating gaze between columns to match test answers
Developmentally Targeted Interventions
Cards and board games for shifting gaze in same and different focal lengths

Fig. 9-16

Model for Management of Visual-Motor Dysfunction: Math Domain

Model for Management of Visual-Motor Dysfunction (fig. 9-16)

Individualized Management Program

Math Domain

Goal: To improve math concepts

Objective: Given numbers between 1 and 999,999, Melinda will be able to recognize, read, and write in digits all numbers correctly three out of four times.

Visual Component: Gaze shift

Visual Present Level of Function: Alternate glances from one target to another in the same focal length in near space (3"-12") are accomplished with some difficulty and blinking, and from target in near space to another in middle space (1'-6') with significant difficulty and inaccuracy.

Visual Procedures

Functionally Appropriate Adaptation: Copying numbers will be easier for Melinda from a page on her desk than from the chalkboard. Her classroom teacher can show Melinda how to use two straight edges for shifting gaze from one column of words or numbers to another. One is placed below the answer blank in one column; the other can mark the correct matching symbol, so that she can relocalize to check accuracy instead of having to re-examine the entire column (fig. 9-17).

Developmentally Targeted Interventions: Playing games such as dominoes with her mother and cards with her grandmother can provide practice shifting gaze from one set of numbers, pictures, or other symbols to another in the same focal length (near space) and between different focal lengths (near and middle space) without the stress of academic components (figs. 9-18, 9-19, 9-20).

Fig. 9-17

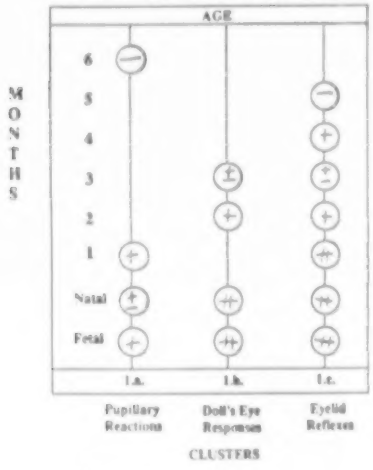
Fig. 9-18

Fig. 9-19

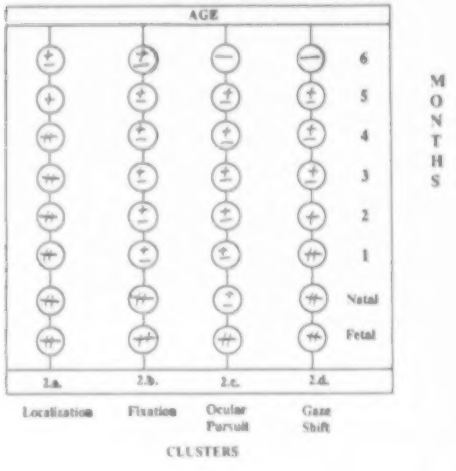
Fig. 9-20

Score Sheet (Developmental Levels)

Section 1. Primarily Involuntary Visual Patterns (Reflexive)



Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)



Summary

Periodic Blink: 30 per minute (during conversation)
SECTION 1. Primarily Involuntary Visual Patterns (Reflexive) 0 - 4 months
SECTION 2. Primarily Voluntary Eye Movements (Cognitively-directed) 0 - 6 months

Subject: Melinda Y Examiner: Erhardt Test Date: 6/25/86

Birthdate: 9-11-72 Chronological Age: 13½ Years Diagnoses: Cerebral Palsy

Assessment Report

Summary and conclusions: Reflexive visual immaturity affects Melinda's functional vision as sluggish pupillary reactions and unequal eyelid opening correlate with excessive sensitivity to normal light levels. The involuntary doll's eye responses interfere with precise eye-head shifts.

Immediate and accurate visual localizations to environmental stimuli are both a strength and a potential problem unless Melinda can ignore extraneous input while maintaining attention to classroom tasks.

Melinda is unable to achieve fusion and uses alternating monocular fixation, which is functional for most activities of daily living not requiring intense three-dimensional perception. For near space she prefers right eye fixation. Her difficulty sustaining fixation is related to generally poor stability/mobility control (stabilizing part of the body to move another part efficiently). This problem affects visual tracking as well as gaze shifts, since Melinda is often in constant motion, ranging from wide to very small ranges, and has not perfected precise eye movements separate from her head.

General recommendations: At Melinda's age, certain visual/postural compensations are subcortically integrated with functional skills such as reading and writing. Imposing significant changes in the motor components of an academic task may interfere with cognitive processing. Functionally appropriate adaptations, however, that can reduce stress and visual fatigue include the following:

1. amber corrective lenses
2. more external postural stability and flexibility in classroom positioning
3. reduction of sensory stimulation, especially during tests
4. elimination of speed requirements
5. use of adaptive educational aids

Developmentally targeted interventions can be structured to increase Melinda's awareness and eye-hand coordination. Tasks should be presented in a manageable series of steps and all procedures linked to motivating activities of daily living.

Re-evaluation is recommended in one year.

Signature

References

Andrist, S. 1988. Personal communication.

Colliton, P. 1986. Personal communication.

Suchoff, I.B., and T.G. Petito. 1986. The efficacy of visual therapy: Accommodative disorders and non-strabismic anomalies of binocular vision. *Journal of the American Optometric Association* 57(2):119-124.

Chapter Ten
Nathan: Assessment and Management

Date: January 29, 1989

To: Whom It May Concern

Re: Occupational Therapy Evaluation for Nathan Johnson

This 8½-year-old male with a diagnosis of cerebral palsy was re-evaluated with the Erhardt Developmental Vision Assessment (EDVA) which measures the motor components of vision, both reflexive visual patterns and voluntary eye movements of localization, fixation, ocular pursuit, and gaze shift. Nathan's eye muscles, both involuntary and voluntary, have been affected by cerebral palsy, which is defined as a condition in which damage has occurred to areas of the brain that control the motor system.

The most recent ophthalmology report stated that Nathan's visual acuity measured 20/400 at worst and possibly much better. Cycloplegic examination (drops to dilate the pupils) revealed moderate hyperopia. A large degree of exotropia affected both eyes, right eye more often. According to the ophthalmologist, Nathan's visual deficit was neural (in the brain) rather than optical (in the eye), and therefore not correctable with glasses (Letson 1987).

Current optometric examination revealed a constant alternating exotropia, which means use of one eye at a time (monocular), with his left eye deviating more often than the right, indicating more frequent use of the right eye. According to the visuoscopy, he does use each fovea for fixation, although the left eye was a little off center. The amount of exotropia (turning of the eye) was significant, approximately 65-70 prism diopters.

Ophthalmoscopy was negative for pathology of the visual structures. Retinoscopy showed significant uncorrected hyperopia (farsightedness), measuring +5.50 O.D. (right eye) and +4.50 O.S. (left eye), which requires Nathan to accommodate between 8 diopters and 9 diopters for close work. Normally, 8-year-olds have an amplitude of 15 diopters, but children with Nathan's degree of physical impairment have almost no accommodative ability (focusing), and cannot hold focus more than three to four seconds, even with enormous effort. He was tested with the Broken Wheel cards, which are meant to test distance acuity, but in order to elicit responses, the cards were held closer, and the numbers were adjusted accordingly. Nathan gave consistent responses up to 20/500, but his optometrists felt that he was capable of better visual acuity. Ocular motility was poor in both eyes. Corrective lenses for hyperopia (+5.50 O.D. and +5.00 O.S.) were prescribed for full-time use, especially in school and for the computer. A patching regime was recommended for ocular motility training only (Duckman 1989; Miller 1989).

Consultation with Nathan's optometrists included discussion of the optometric findings and those of the EDVA, analysis of Nathan's probable developmental course that led to his specific visual and postural compensations, and consensual recommendations for management.

A summary of the results will include comparison with the previous evaluation (January 1986), the relationship of specific visual findings to the total motor action system, and implications for function in home, school, and community environments. Recommendations for a management program integrated with Nathan's individualized educational plan will include functionally appropriate adaptations and developmentally targeted interventions.

Nathan qualifies for special services including a teacher certified in physically handicapped, occupational and physical therapy, full-time classroom aide, adaptive physical education, speech/language services, and mainstream experiences with non-handicapped peers during selected academic curricula in the regular education classroom.

Section I. Primarily Involuntary Visual Patterns (Reflexive)

I. a. PUPILLARY REACTIONS

Stimuli: Penlight (**weak** light) and Flashlight (**strong** light) directed into one eye within 12" in dimly lit room

Functional Implications: Tests rapidity of environmental adaptation since light is the first activation of the visual system

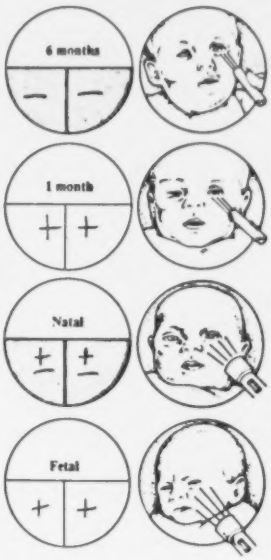
Developmental Levels	
Right	Left

Pattern Components	
R	L
Eye	

Direct Light Reflex

Pattern Components	
R	L
Eye	

Consensual Light Reflex
(stimulation of one pupil results in equal constriction of both)



- Pupil constricts quickly to **weak** light directed into eye
- Pupil dilates quickly when **weak** light is removed from eye
- Pupil constricts quickly and equally to **weak** light directed into **other** eye
- Pupil dilates quickly and equally when **weak** light is removed from **other** eye
- Pupil constricts slowly to **weak** light directed into eye
- Pupil dilates slowly when **weak** light is removed from eye
- Pupil constricts slowly and equally to **weak** light directed into **other** eye
- Pupil dilates slowly and equally when **weak** light is removed from **other** eye
- Pupil constricts quickly to **strong** light directed into eye
- Pupil dilates quickly when **strong** light is removed from eye
- Pupil constricts quickly and equally to **strong** light directed into **other** eye
- Pupil dilates quickly and equally when **strong** light is removed from **other** eye

Late Stage (8-9 months)

- Pupil constricts slowly to **strong** light directed into eye
- Pupil dilates slowly when **strong** light is removed from eye

Late Stage (8-9 months)

- Pupil constricts slowly and equally to **strong** light directed into **other** eye
- Pupil dilates slowly and equally when **strong** light is removed from **other** eye

Early Stage (6-7 months)

- No pupil constriction to **weak** light directed into eye
- No pupil constriction to **strong** light directed into eye

Early Stage (6-7 months)

- No pupil constriction to **weak** light directed into **other** eye
- No pupil constriction to **strong** light directed into **other** eye

I.b. DOLL'S EYE RESPONSES

Stimuli: Passive movement of head against body

Functional Implications: Prepares for voluntary separation of eyes from head
Integrated when eyes and head move together voluntarily

Eyes should not be fixating on a target during the rapid passive head-turning

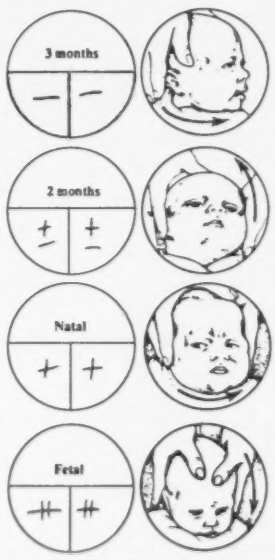
Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction	

Head Rotation

Pattern Components	
R	L
Eye	

Head Flexion/Extension



- Eyes move in same direction as head **rotation**: Integrated
- Eyes move in same direction as head **flexion**: Integrated
- Eyes move in same direction as head **extension**: Integrated
- Delayed or inconsistent eye movements in same direction as head **rotation**: Beginning integration
- Delayed or inconsistent eye movements in same direction as head **flexion**: Beginning integration
- Delayed or inconsistent eye movements in same direction as head **extension**: Beginning integration
- Strong apparent counterrotation of eyes (actually lagging behind) in opposite direction of head rotation during first 10 days, gradually decreasing
- Strong apparent counterrotation of eyes (actually lagging behind) in opposite direction of head **flexion** during first 10 days, gradually decreasing
- Strong apparent counterrotation of eyes (actually lagging behind) in opposite direction of head **extension** during first 10 days, gradually decreasing

Mid Stage (7-8 months)

- Slight apparent counterrotation of eyes (actually lagging behind) in opposite direction of head rotation

Mid Stage (7-8 months)

- Slight apparent counterrotation of eyes (actually lagging behind) in opposite direction of head **flexion**
- Slight apparent counterrotation of eyes (actually lagging behind) in opposite direction of head **extension**

Assessment Report

SECTION 1. Primarily Involuntary Visual Patterns (Reflexive)

1.a. Pupillary Reactions

Clinical observations: Pupils constrict quickly to strong light directed into pupil (direct light reflex) and into opposite pupil (consensual light reflex), but dilate slowly after strong light is removed and react much more slowly to weak light.

Summary and implications for function: Pupillary reactions were generally immediate to strong light, but sluggish to weak light, indicating slower and less efficient adaptation to environment. It is reported that Nathan was particularly sensitive to overhead fluorescent lights. When they were turned off, he was more consistently able to keep his eyes from rolling upward. He needed sunglasses when outside in the bright sun.

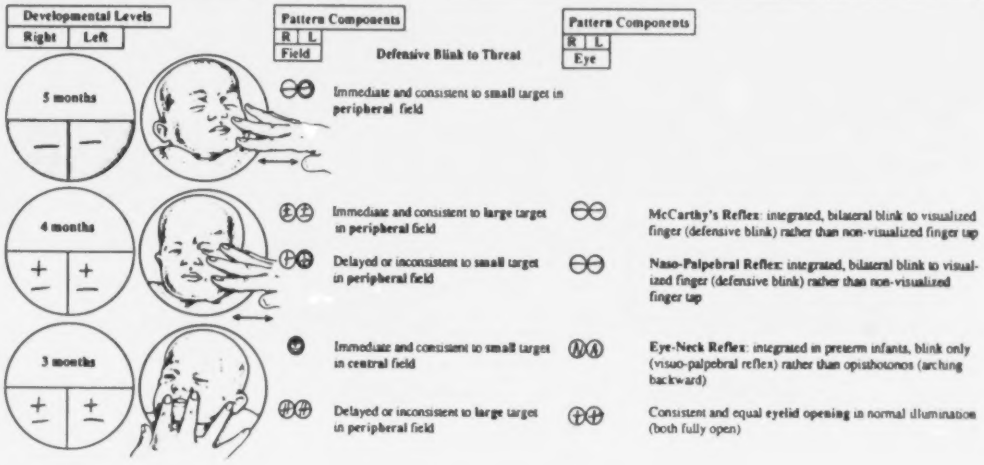
1.b. Doll's Eye Responses

Clinical observations: Eyes beginning to move together with head during rotation to the left, but strong apparent countertorsion of eyes (actually lagging behind) in opposite direction of head flexion and rotation to the right is present as well as delayed eye movements in same direction as head extension.

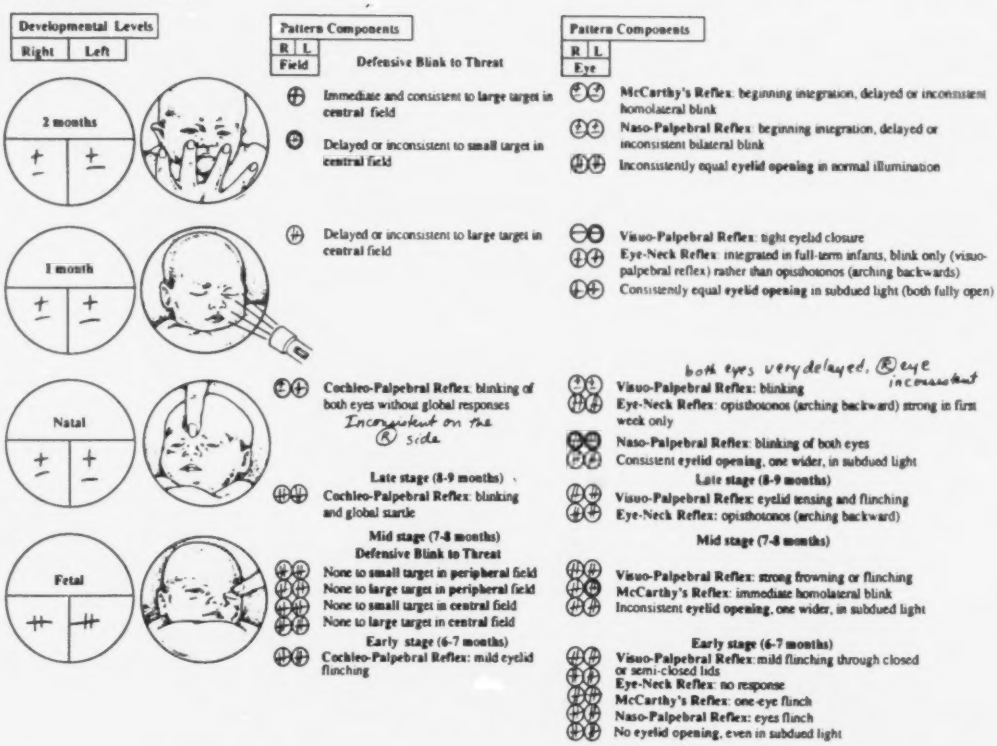
Summary and implications for function: Involuntary eye-head movements interfere with voluntary control, especially during operation of computer and other communication systems.

I.c. EYELID REFLEXES

	Stimuli	Functional Implications
Defensive Blink to Threat	Rapid approach and removal of visualized target (Small: spread fingers; Large: test booklet)	Protects eyes from tactile assault
McCarthy's Reflex	Light non-visualized tap above one eyebrow (supraorbital area)	Activates unilateral eyelid function
Naso-Palpebral Reflex	Light non-visualized tap on bridge of nose	Activates bilateral eyelid function
Eye-Neck Reflex	Bright light in eyes, head unsupported (flashlight)	Primitive survival reaction
Visuo-Palpebral Reflex	Bright light in eyes (flashlight)	Protects eye from excessive light
Cochleo-Palpebral Reflex	Sharp noise (hand clap)	Protects eye from certain non-visual stimuli


Developmental Levels
Right | Left
Pattern Components
R | L
Field
Defensive Blink to Threat
Pattern Components
R | L
Eye
5 months
Immediate and consistent to small target in peripheral field
4 months
Immediate and consistent to large target in peripheral field
Delayed or inconsistent to small target in peripheral field
McCarthy's Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap
Naso-Palpebral Reflex: integrated, bilateral blink to visualized finger (defensive blink) rather than non-visualized finger tap
3 months
Immediate and consistent to small target in central field
Delayed or inconsistent to large target in peripheral field
Eye-Neck Reflex: integrated in preterm infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backward)
Consistent and equal eyelid opening in normal illumination (both fully open)

I. c. EYELID REFLEXES


Developmental Levels
Right | Left
Pattern Components
R | L
Field
Defensive Blink to Threat
Pattern Components
R | L
Eye
2 months
Immediate and consistent to large target in central field
Delayed or inconsistent to small target in central field
McCarthy's Reflex: beginning integration, delayed or inconsistent homolateral blink
Naso-Palpebral Reflex: beginning integration, delayed or inconsistent bilateral blink
Inconsistently equal eyelid opening in normal illumination
1 month
Delayed or inconsistent to large target in central field
Visuo-Palpebral Reflex: tight eyelid closure
Eye-Neck Reflex: integrated in full-term infants, blink only (visuo-palpebral reflex) rather than opisthotonos (arching backwards)
Consistently equal eyelid opening in subdued light (both fully open)
Natal
Cochleo-Palpebral Reflex: blinking of both eyes without global responses
Inconsistent on the ® side
both eyes very delayed, ® eye inconsistent
Visuo-Palpebral Reflex: blinking
Eye-Neck Reflex: opisthotonos (arching backward) strong in first week only
Naso-Palpebral Reflex: blinking of both eyes
Consistent eyelid opening, one wider, in subdued light
Late stage (8-9 months)
Cochleo-Palpebral Reflex: blinking and global startle
Late stage (8-9 months)
Visuo-Palpebral Reflex: eyelid tensing and flinching
Eye-Neck Reflex: opisthotonos (arching backward)
Fetal
Mid stage (7-8 months)
Defensive Blink to Threat
None to small target in peripheral field
None to large target in peripheral field
None to small target in central field
None to large target in central field
Mid stage (7-8 months)
Visuo-Palpebral Reflex: strong frowning or flinching
McCarthy's Reflex: immediate homolateral blink
Inconsistent eyelid opening, one wider, in subdued light
Early stage (6-7 months)
Cochleo-Palpebral Reflex: mild eyelid flinching
Early stage (6-7 months)
Visuo-Palpebral Reflex: mild flinching through closed or semi-closed lids
Eye-Neck Reflex: no response
McCarthy's Reflex: one-eye flinch
Naso-Palpebral Reflex: eyes flinch
No eyelid opening, even in subdued light

Assessment Report

1.c. Eyelid Reflexes

Clinical observations: Immediate and consistent defensive blink to large target in central field; slightly delayed and / or inconsistent blink to large target in peripheral field and to small target in central field, very delayed to small target in peripheral field;

Consistently equal eyelid opening;

Immediate and consistent cochleo-palpebral reflex on the left, inconsistent on the right;

Very delayed visuo-palpebral reflex (blink to light directed into eye);

Tactile reflexes (McCarthy's and naso-palpebral) not integrated

Summary and implications for function: Nathan's defensive blinks show a sequential developmental delay and need to be more consistent, immediate, and automatic to protect his eyes from injury. Delayed responses indicate the need for more rapid activation of his visual-motor system.

General goal: Reflexes such as the defensive blink need to be more immediate and consistent as visual stimuli replace the more primitive tactile stimuli.

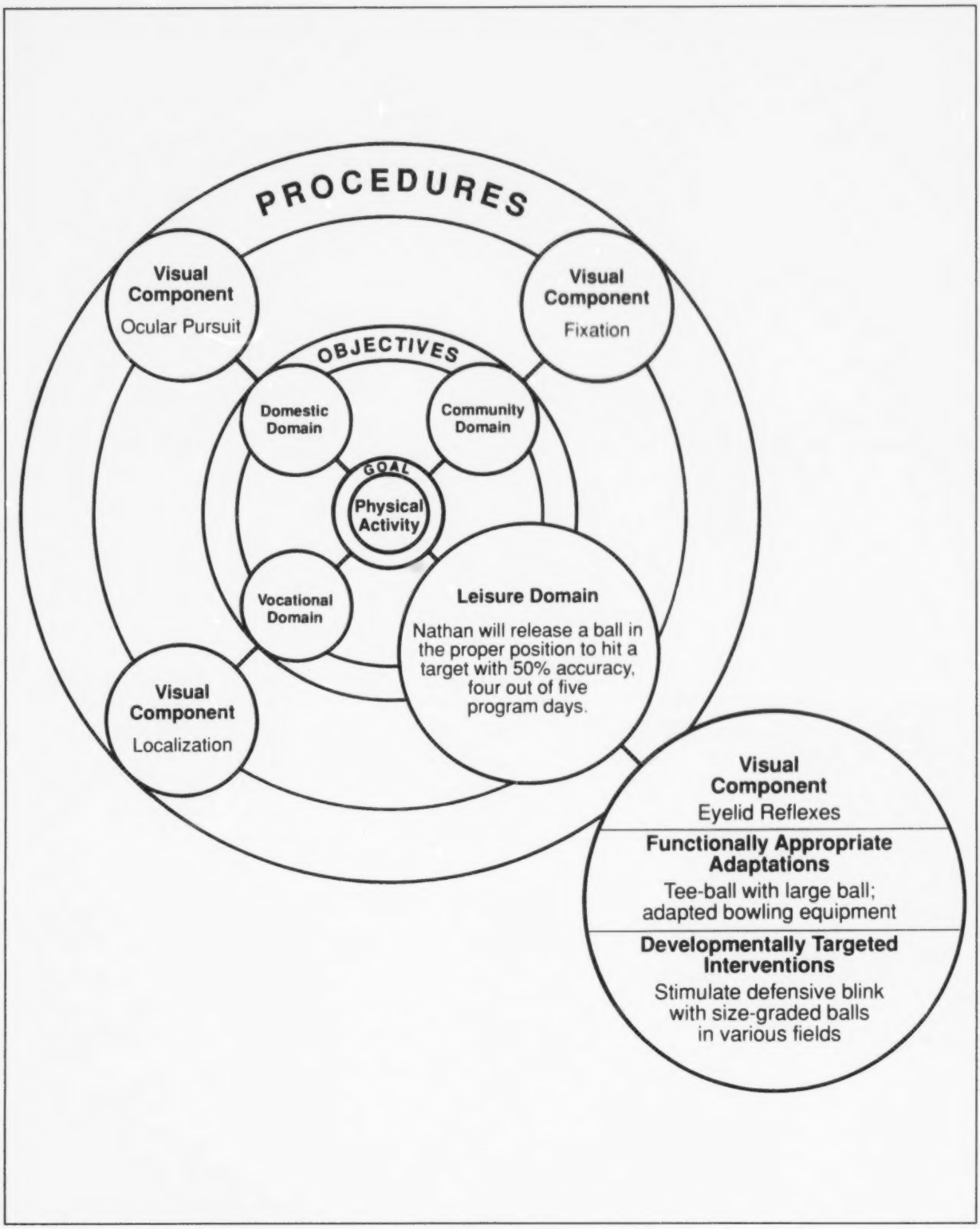


Fig. 10-1

Model for Management of Visual-Motor Dysfunction: Leisure Domain

Model for Management of Visual-Motor Dysfunction (fig. 10-1)

Individualized Management Program

Leisure Domain

Goal: To improve participation in age-appropriate physical activities

Objective: Nathan will release a ball in the proper position to hit a target with 50% accuracy on four out of five program days.

Visual Component: Eyelid reflexes

Visual Present Level of Function: Nathan's defensive blinks show a sequential developmental delay and need to be more consistent, immediate, and automatic to protect his eyes from injury. Delayed responses indicate the need for more rapid activation of his visual-motor system.

Visual Procedures

Functionally Appropriate Adaptations: Nathan practiced Tee-ball with his grandparents and brother. Before placing a large ball (basketball) on the tee, his grandfather pushed it toward Nathan's face, stopping inches from his eyes, which blinked immediately. Nathan's brother held the ball on the tee while Nathan was helped to swing the bat (figs. 10-2, 10-3). He is learning to use his powered chair to move around the bases while participating in the summer recreation program with nonhandicapped peers, and he posed for the team picture (fig. 10-4).

Fig. 10-2

Fig. 10-3

Fig. 10-4

When joining friends at a bowling alley, Nathan uses adapted bowling and seating equipment (fig. 10-5).

Developmentally Targeted Interventions: During adapted physical education activities, in preparation for releasing a ball to roll down an incline and hit a target, Nathan can be presented with a large ball in various fields in rapid succession to elicit a more immediate and consistent offensive blink. Ball size can gradually be reduced as consistency improves.

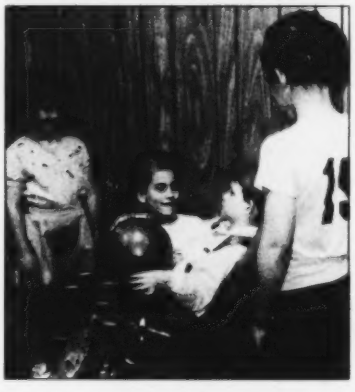


Fig. 10-5

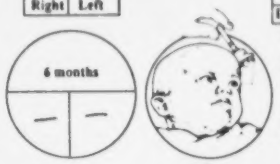
Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)

2. a. LOCALIZATION (VISUAL APPROACH)

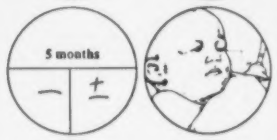
Target Size	Focal Lengths	Stimuli
Large: bigger than examiner's hand Small: size of hand or smaller Tiny: pellet size	Near space: 3-12" Middle space: 1-6' Far space: 6-20' Distant space: 20'-infinity	Light Sound Faces Contour Movement

Developmental Levels: Right | Left

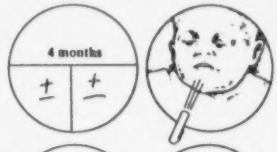
Pattern Components: R | L; Direction



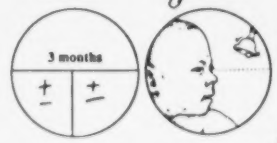
Eyes localize, then **hand** approaches and contacts tiny target
Eyes move independently from stabilized **head** to localize target
Localizes non-vocalizing **face** in far space
Localizes large target by **contour/pattern** in **far** space
Adjusts **body** position to localize target more easily
Turns to side, then up, to localize non-visualized **sound** above ear
Turns in arc movement to localize non-visualized **sound** below ear



Eyes and **hand** pursue lost small target outside visual field
Eyes localize tiny target in near space, without **hand** approach
Eyes begin to move independently from stabilized **head** to localize target
Localizes vocalizing **face** in far space
Localizes large **moving** target in **far** space
Localizes small target by **contour/pattern** in **middle** space
Turns to side, then down, to localize non-visualized **sound** below ear



Eyes localize and **hand** grasps small **target** in near space
Eyes, not **hand**, pursue lost small target outside of visual field
Smiles at own **face** in mirror spontaneously or when tapped
Localizes large target by **contour/pattern** in **middle** space
From side / From above / From below > Localizes **penlight** moving slowly into peripheral field in an arc 12" away at 90° from central fixation point (tested in subdued light)
45° from (R), 60° from (L), 45° from above, 45° from below



Eyes and **head** move together consistently to localize target
Eyes regard own **hand** spontaneously
Prompt regard to target presented **centrally** (in body midline)
Eyes localize and **hand** approaches, contacting small target in near space
Eyes glance briefly at target in own moving **hand**
Localizes large **moving** target in **middle** space
Eyes turn to target with sound properties placed in own hand
Turns toward side of non-visualized **sound** 18" from ear
Localizes non-vocalizing face in middle space

rotates head, eyes lag, especially to the (R), rotates head further, hand touches, loses fixation

---

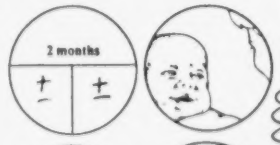
2. a. LOCALIZATION (VISUAL APPROACH)

Testing localization to diffuse light. Subject is observed during slow rotation away from light, for head derotation toward light.

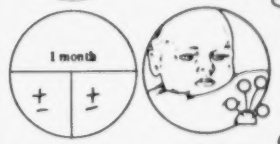
Testing localization of penlight moving into peripheral field from each side and above: Examiner stands behind subject who is fixating on another target at central fixation point. To test from below: Subject reclines as target is brought upward from feet.

Developmental Levels: Right | Left

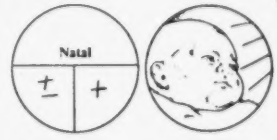
Pattern Components: R | L; Direction



Eyes glance at own moving **hand/fingers**
Delayed regard to target presented **centrally** from below (viewed at chest level)
Turns to target in **peripheral** surroundings
Localizes **penlight** moving slowly into peripheral field in an arc 12" away at 30° from central fixation point
Localizes small target with internal **movement** up to 3' away
Localizes large target with internal **movement** in **middle** space
Localizes non-vocalizing **face** in near space delayed to the (R)
Localizes vocalizing **face** in middle space
Turns toward general direction of non-visualized **sound** source



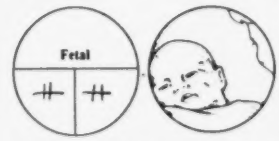
Eyes and **head** move together inconsistently during voluntary movements
Localizes diffuse **light** source
Localizes small target with internal **movement** up to 12" away
Brief glances at large target with internal **movement** in **middle** space
Brief regard of non-vocalizing **face** in near space
Localizes vocalizing face in near space delayed to the (R)



Random **eye** movements, not together with random **head** and **body** movements
Diffuse distractibility to target in **peripheral** surroundings
Turns toward large areas of **light**
Localizes small target with internal **movement** exactly 8" away

Late Stage (8-9 months)

Turns toward diffuse **light**
Faint interest in **peripheral** surroundings
Localizes focalized **light** (penlight) moving into peripheral field at central fixation point
Widens eyes and attends to pleasant non-visualized **sound** without head turning



Early Stage (6-7 months)

No response to visual target
No head-turning toward diffuse **light**
Involuntary eyeball movements in all directions, even under closed lids
Mild eyelid flinching to non-visualized **sound**
No head-turning toward focalized **light**

Assessment Report

SECTION 2. Primarily Voluntary Eye Movements (Cognitively Directed)

2.a. Localization (Visual Approach)

Clinical observations: Localizes *all* targets in the left field more accurately, immediately, and consistently than in the right;

Turns toward the side of the unseen sound source without accurate localization; has difficulty localizing sounds above or below the ear;

Localizes faces, especially vocalizing ones, in near and middle space, but not in far space or spontaneously to mirror image;

Localizes target with internal movement in near space and large moving target in middle space, but does not localize moving targets in far space;

Can localize large target in middle space by contour/pattern only;

Delayed localization to penlight moving into peripheral fields from the right, above, and below at 45 degrees from central fixation point; better from the left at 60 degrees (normally 90 degrees);

Eyes beginning to move separately from head toward the left to voluntarily localize target in left field, but eyes lag behind head when turning toward the right; many random involuntary eyeball movements still occur, primarily to the left and upward, not together with head movements;

No spontaneous hand regard; eyes glance at own hand or target placed in hand upon command;

Turns to target presented peripherally (to the side) more easily than centrally (midline)

Summary and implications for function: Nathan's strongest skills appear to be in localization, helping him indicate choices in both school and home environments. He responds best to vocalizing faces and other targets with sound and movement in his left field, near space. Localization of targets in the right field and those in middle and far space is more difficult. His preference for the left visual field may have developed because of more efficient left hand function for reaching. Frequency of functional head rotation has helped integrate the doll's eye response, allowing the eyes and head to move together. Head rotation to the right, however, is inefficient because the strong doll's eye causes the eyes to lag behind the head, forcing Nathan to rotate his head excessively in order to bring his eyes into the field of vision. Although presentation of educational materials in the left field produces more immediate and consistent responses, persistent orientation in that direction jeopardizes body symmetry and increases rotational scoliosis, putting Nathan at risk for subluxation or dislocation of his right hip.

General goal: Localization activities should expand Nathan's functional visual field to the right and his focal length to middle and to far space if possible.

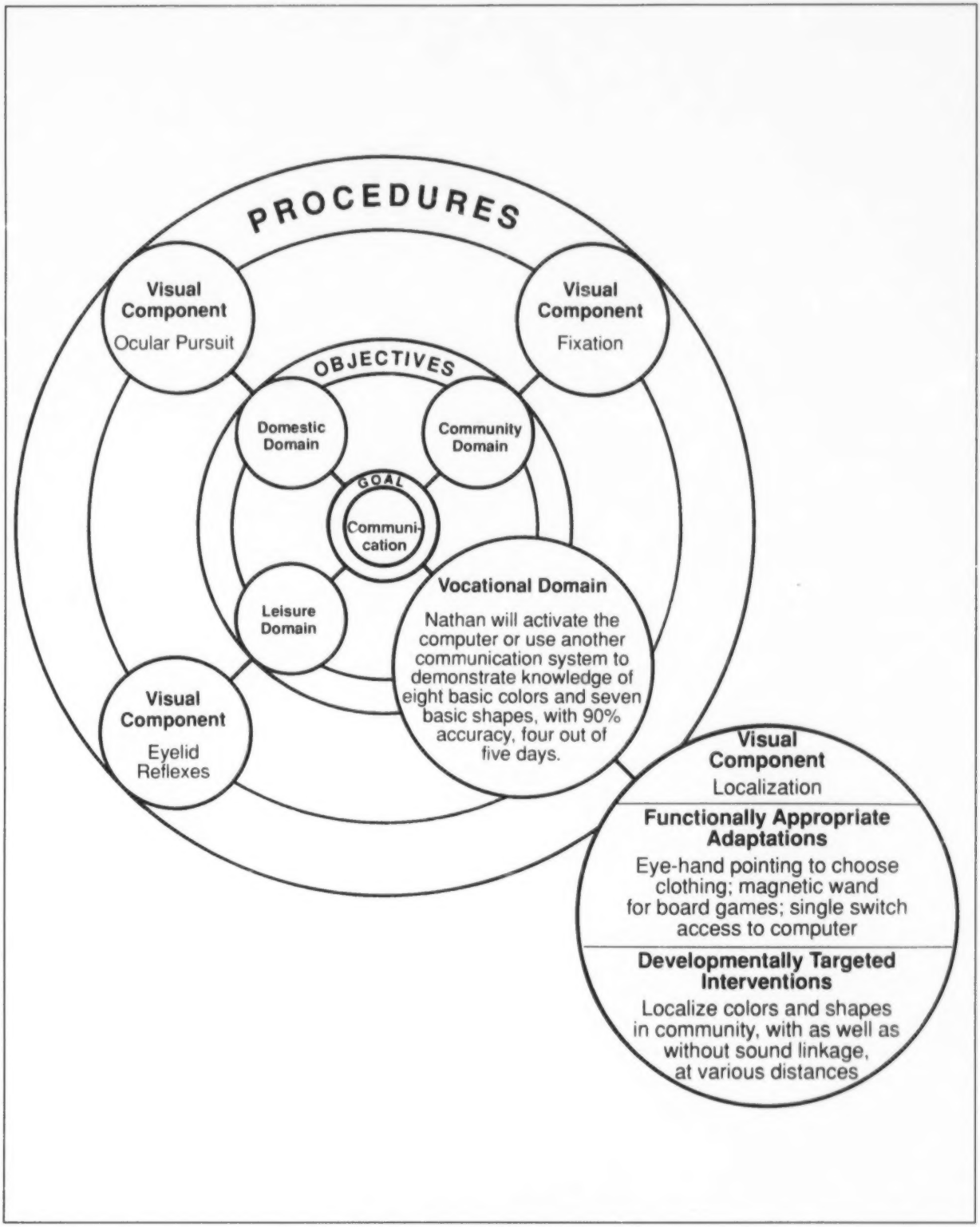

PROCEDURES
Visual Component
Ocular Pursuit
Visual Component
Fixation
OBJECTIVES
Domestic Domain
Community Domain
GOAL
Communi-cation
Leisure Domain
Vocational Domain
Nathan will activate the computer or use another communication system to demonstrate knowledge of eight basic colors and seven basic shapes, with 90% accuracy, four out of five days.
Visual Component
Eyelid Reflexes
Visual Component
Localization
Functionally Appropriate Adaptations
Eye-hand pointing to choose clothing; magnetic wand for board games; single switch access to computer
Developmentally Targeted Interventions
Localize colors and shapes in community, with as well as without sound linkage, at various distances

Fig. 10-6

Model for Management of Visual-Motor Dysfunction: Vocational Domain

Model for Management of Visual-Motor Dysfunction (fig. 10-6)

Individualized Management Program

Vocational Domain

Goal: To improve cognitive and communicative skills

Objective: Using one of his present communication systems, Nathan will demonstrate knowledge of eight basic colors, with 90% accuracy, four out of five days.

Objective: Nathan will demonstrate knowledge of seven basic shapes by using three modalities of communication over three different days.

Objective: Nathan will independently activate the computer or other augmentative communication system, increasing the number of responses 50% above his current rate.

Visual Component: Localization

Visual Present Level of Function: Nathan's strongest skills appeared to be in localization, helping him indicate choices in both school and home environments. He responds best to vocalizing faces and other targets with sound and movement, in his left field, near space. Localization is more difficult to targets in the right field and those in middle and far space. His preference for the left visual field may have developed because of more efficient left hand function for reaching. Frequency of functional head rotation has helped integrate the doll's eye response, allowing the eyes and head to move together. Head rotation to the right, however, is inefficient because the strong doll's eye response causes the eyes to lag behind the head, forcing Nathan to rotate his head excessively in order to bring his eyes into the field of vision. Although presentation of educational materials in the left field produces more immediate and consistent responses, persistent orientation in that direction jeopardizes body symmetry and increases rotational scoliosis, putting Nathan at risk for subluxation or dislocation of his hip. Voluntary reaching is significantly influenced by the doll's eye response and the asymmetrical tonic neck reflex (ATNR). He reaches and swipes with one arm and sustains grasp if an object is placed in his hand, but cannot combine reach and grasp efficiently. By reaching and raking, however, he successfully pulls his grandfather's glasses off his face (figs. 10-7, 10-8, 10-9).

Fig. 10-7

Fig. 10-8

Fig. 10-9

Effective access to augmentative communication and mobility and environmental control was achieved after a long period of experimentation with a variety of switches (flat, leaf, wobble, round, and joystick) and a universal switch mounting system.

This process was spearheaded by Nathan's speech clinician, but it involved almost every member of Nathan's team.

For example, with Nathan positioned in his stander, a wobble switch was first placed in his left visual field, where his eyes and hand could reach and touch it most easily (fig. 10-10). Primitive reflexes such as the ATNR dominated those eye-head-arm postures and movements. Even when the switch was moved closer to midline, the process of localizing and relocalizing to the computer monitor for every activation was obviously slow and inefficient (fig. 10-11).

Fig. 10-10

Fig. 10-11

A large round pressure switch was then placed in his left central rather than left peripheral field. His right arm was stabilized, and a customized trough was attached to his travel chair to support the left arm during the minimal arm movement forward required to activate the switch. Thus Nathan needed to localize visually and manually to the switch, relocalize visually only once to the monitor screen, and then simply maintain visual fixation while operating the switch with his hand to follow his learning-disability teacher's instruction (figs. 10-12, 10-13).

Other uses of the wobble switch were explored. It was mounted on a gooseneck base and attached to a motorized scooter board. By maintaining grasp on the one-directional switch, Nathan was able to move successfully into his classroom, indicating potential for future use of a powered chair (fig. 10-14).

Fig. 10-12

Fig. 10-13

Fig. 10-14

Fig. 10-15

Finally, a control interface box for microcomputer control was mounted on a powered chair, positioned for access by Nathan's *right* arm, elbow slightly flexed, forearm in midposition between pronation and supination, wrist extended, and fisted hand grasping a heavy-duty joystick. The joystick was inserted into a T-switch, which prevented his hand from sliding up and off, and was gated to allow only four directions: forward, backward, left, and right. During a trial assessment, his first experience in the powered chair, Nathan was alert and responsive to verbal directions. He kept his head in midline, maintained grasp, and used short discrete arm excursions without extraneous body movements to independently operate the chair at its lowest speed for almost 15 minutes within an obstacle-free space (fig. 10-15).

Without needing to visually monitor his hand, Nathan can improve his ambient vision, directionality, and motor-planning skills as he expands his mobility in home, school, and community.

Visual Procedures

Functionally Appropriate Adaptations: The round pressure switch, when used according to procedures and adaptations determined through the team evaluation process, can provide access to the computer for academic programs. The joystick and control interface box can operate the computer and also the powered chair and in the future, environmental systems such as lights, radio, television, fan, telephone, and intercom.

In preparation for getting dressed in the morning, Nathan could indicate to his mother his choice of two outfits of different colors by pointing with his eyes and hand.

Nathan's neighbor (also his classroom aide) helps him play the "pizza" game with nonhandicapped neighborhood friends by placing a magnetic wand in his hand so that he can localize a specific "food" by its color (mushroom/brown, tomato/red, and pepper/green), pick it up, and place it on the matched color spot on the "pizza slice" (figs. 10-16, 10-17).

Developmentally Targeted Interventions: To improve accuracy of localization to sound and thus facilitate eye movements, targets with various sounds, colors, and shapes should be presented to Nathan for identification, twice as often to the right as to the left, in near space, and gradually in middle

Fig. 10-16

Fig. 10-17

space. Nathan's speech clinician should then have him answer questions by pointing to pictures indicating "Yes" and "No" (fig. 10-18).

To improve visual localization without sound, Nathan's mother as well as other family members, school staff, classmates, and neighbors could approach him soundlessly, waiting for his facial/social/vocal response before greeting him verbally, in central and peripheral fields, and middle as well as near space (fig. 10-19).

Bilateral hand use, important for symmetry and the next sequential skill after unilateral swiping, can be combined with primitive squeeze grasp (approaches object if within 1 inch) in a highly motivating activity, such as holding a steering wheel. Nathan, like most children, enjoys pretending he is driving a car, particularly the bumper cars at the state fair. The ability to sustain grasp during finely graded arm movements and visual localization of obstacles is necessary for operation of a joystick on a powered chair.

Fig. 10-18

Fig. 10-19

During swimming therapy with his physical therapist, Nathan can be asked to localize specific shapes and colors on the wall in far space (fig. 10-20). While riding in his father's car, Nathan can be encouraged to identify colors of targets such as buildings, signs, or Christmas lights in all fields in distant space, twice as often to the right (fig. 10-21).

Fig. 10-20

Fig. 10-21

2. b. FIXATION (VISUAL GRASP)

Modes of Visual Processing
Ambient: passive stare, with awareness of surroundings Focal: active focus on target, excluding surroundings

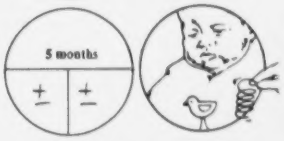
Approximate Functional Focal Lengths		
Near Space: 3-12"	Middle Space: 1-6'	Far Space: 6-20'

Developmental Levels	
Right	Left

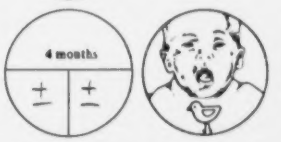
Pattern Components	
R	L
Field (Both Eyes)	

Pattern Components	
R	L
Eye (Other Occluded)	

Intense **focal** fixation with visual responses, global suppressed
Inspects own face in mirror intently
Eyes fixate on tiny target while **hand** approaches and contacts
Fixates at **focal lengths**: 3" - 20"



Maintains **focal** fixation with more visual than global responses
Maintains fixation on stationary target in competition with moving one
Intermittent regard of own face in mirror *when prompted*
Eyes fixate on tiny target without **hand** approach
Fixates on **focal lengths**: 3" - 6'



Efficient **ambient** inspection of surroundings in middle and far space
Eyes maintain fixation on small target in **hand**
Prolonged, selective **focal** fixation with multiple global responses
Uses **ambient** starey fixation on surroundings to rest from intense focal fixation
Consistent **binocular fixation**
Eyes fixate recurrently and with delay on tiny target without **hand** approach
Fixates at **focal lengths**: 4" - 5'

Maintains fixation on non-vocalizing **face** for 10 seconds *7 seconds*
Crude **ambient** inspection of surroundings in middle and far space
Direct, discriminative **focal** fixation on target in midline *needs motivating target*
Inconsistent binocular fixation
Eyes fixate briefly on small target placed in own **hand**
Prolonged fixation on target with rhythmical movement
Maintains fixation on stationary target unless distracted by moving one
Fixates at **focal lengths**: 5" - 3'

needs (R) hand supported close to midline

needs (L) hand supported

---

2. b. FIXATION (VISUAL GRASP)

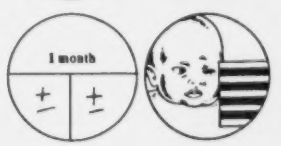
Fixation Criteria (Global responses mature to visual only)	
Global Eyes and mouth open, increased or decreased respiration, muscle tone, or body activity	**Visual** Pupils constricted, eyes round rather than oval, upper eyelids tensed and raised, eyes relatively immobile

Developmental Levels	
Right	Left

Pattern Components	
R	L
Field (Both Eyes)	

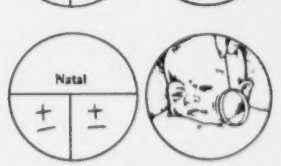
Pattern Components	
R	L
Eye (Other Occluded)	

Direct discriminating **focal** fixation on target at the side of midline
Maintains fixation on vocalizing **face** for 10 seconds *7 seconds*
Beginning **binocular fixation** with blinking and overconvergence
Eyes regard **hand** in ATNR position (head facing extended arm, other flexed)
Fixates longer on black and white bull's eye **pattern** than stripes
Fixates at **focal lengths**: 6" - 2'
Uses alternating monocular, (R) eye more frequently than (L), but skill level is similar. Opposite eye deviates outward.



Brief **focal** fixation on target at the side of midline *Fixates best with (R) eye in (L) field.*
Fleeting regard of non-vocalizing **face**
Brief fixation on vocalizing **face** for 2-3 seconds
Defined **monocular fixation**: active eye fixates on target, other shifts nasally
Bi-ocular fixation (alternating **monocular**): fixation alternates ~~rapidly~~ between both eyes, which shift with head in rhythmical lateral excursions
Roving eyes become relatively immobile, with **ambient** stare at surroundings
Fixates longer on black and white stripes than bull's eye **pattern**
Fixates at **focal lengths**: 7" - 12" *Suppresses vision in opposite eye when alternating*

Delayed to target in (R) field



Tries to achieve focal fixation on target at side of midline, with some global responses
Vague, intermittent, **ambient** regard of surroundings
Crude **monocular fixation**: active eye aligns, tries to immobilize and fixate momentarily on target while inactive eye closes or deviates nasally or temporally
Regards target with internal **movement** placed in line of vision *must be moving*
Maintains **ambient** gaze toward diffuse light by turning head when slowly rotated away
Fixates longer on black and white **pattern** than on target without pattern/contrast
Fixates at **focal length**: 8"

Late stage (8-9 months)
Immobilizes eyes briefly in pseudo-fixation (diffuse, passive, **ambient**)
Mid stage (7-8 months)
Briefly alert to target with **movement** properties (agitated or dangling)
Early stage (6-7 months)
No **focal** fixation
No immobilization of eyes in **ambient** stare at surroundings
No **ambient** gaze toward light

Assessment Report

2.b. Fixation (Visual Grasp)

Clinical observations: Global responses rather than visual only (opens mouth and increases muscle tone in effort to fixate); crude ambient processing (inspection of surroundings in middle and far space); direct, discriminating focal fixation on targets presented at the side, but not in midline, better in the *left* field than the right, with best focal length 12 inches to 14 inches;

Alternating monocular rather than binocular fixation, with inactive eye exotropic (deviating temporally or toward the ear), *right* eye used more frequently than left, although skill levels in each eye are similar, during occlusion as well as with both eyes open;

Fixation maintained on faces for seven seconds (but on own mirror image briefly and only when prompted), on target with internal movement placed in line of vision, and on black-and-white patterns longer than those without pattern/contrast;

Eyes regard hand in ATNR position only, left better than right, unless external wrist support is given

Summary and implications for function: Nathan uses one eye at a time (right more frequently), and fixates best on targets in his left visual field in near space, especially faces. He fixates on his own hand only in the ATNR position. Inability to immobilize his eyes for sustained fixation has interfered with discrimination of educational materials as well as efficient inspection of middle space for operation of a powered chair. Nathan relies on his visual memory after brief glances, especially when he needs to process simultaneous auditory information or activate his arm to point.

General goal: Emphasis should be on increasing duration of fixation.

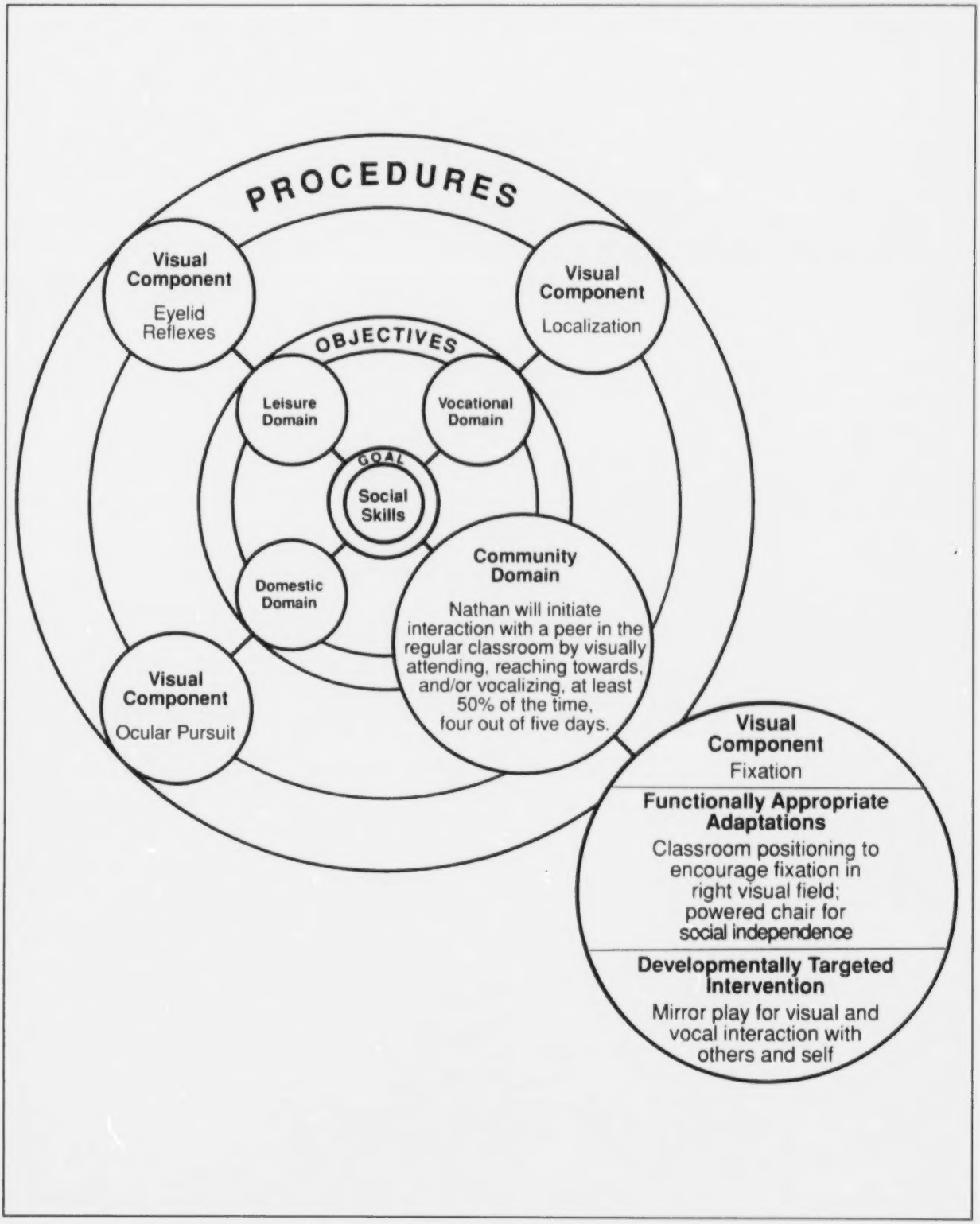

PROCEDURES
Visual Component
Eyelid Reflexes
Visual Component
Localization
OBJECTIVES
Leisure Domain
Vocational Domain
GOAL
Social Skills
Domestic Domain
Community Domain
Nathan will initiate interaction with a peer in the regular classroom by visually attending, reaching towards, and/or vocalizing, at least 50% of the time, four out of five days.
Visual Component
Ocular Pursuit
Visual Component
Fixation
Functionally Appropriate Adaptations
Classroom positioning to encourage fixation in right visual field; powered chair for social independence
Developmentally Targeted Intervention
Mirror play for visual and vocal interaction with others and self

Fig. 10-22

Model for Management of Visual-Motor Dysfunction: Community Domain

Model for Management of Visual-Motor Dysfunction (fig. 10-22)

Individualized Management Program

Community Domain

Goal: To improve social and mobility skills

Objective: In the mainstream classroom, Nathan will initiate interaction with a "special buddy" peer, assigned weekly, by visually attending, reaching towards, and/or vocalizing, at least 50% of the time, four out of five program days.

Visual Component: Fixation

Visual Present Level of Function: Nathan uses one eye at a time (right more frequently) and fixates best on targets, especially faces, in his left visual field in near space. He fixates on his own hand only in the ATNR position. Inability to immobilize his eyes for sustained fixation has interfered with discrimination of educational materials as well as efficient inspection of middle space for operation of a powered chair. Nathan relies on his visual memory after brief glances, especially when he needs to process simultaneous auditory information or activate his arm to point.

Fig. 10-23

Visual Procedures

Functionally Appropriate Adaptations: When mainstreamed in the classroom with nonhandicapped peers, Nathan is positioned to encourage fixation on the vocalizing teacher in his right visual field. His special education teacher stifles a smile as he fixates on the girl beside him instead of the group activity, slowly reaching toward her braids, obviously initiating social interaction (fig. 10-23).

Additional motivation to interact independently with his classmates is encouraged as Nathan learns to scan his entire visual field (ambient awareness) while maneuvering his powered chair in the hall from one classroom to another.

Developmentally Targeted Interventions: A mirror can be set up for cooperative play with his brother as well as independent play, encouraging Nathan to vocalize spontaneously and maintain fixation during visual and vocal interaction, first with his brother's face, then his brother's mirror image, and eventually his own image (fig. 10-24).

Fig. 10-24

2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

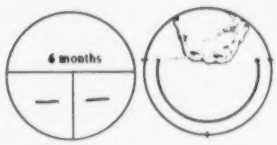
Approximate Functional Focal Lengths	
Near Space: 3 - 12"	Far Space: 6 - 20'
Middle Space: 1 - 6'	Distant Space: 20' - infinity

Compensatory Eye Movements: Eyes remain on stationary target during active head movements

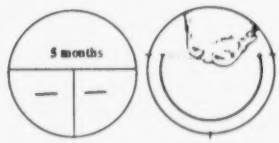
Developmental Levels	
Right	Left

Pattern Components: R | L — Direction (Both Eyes)

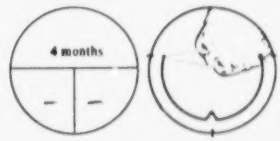
Pattern Components: R | L — Eye (Other Occluded)



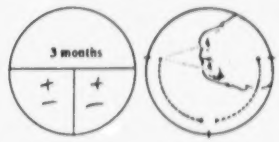
- Eyes move independently from **head** to extreme right/left fields while tracking
- Tracks target **horizontally 180°** smoothly at all speeds, **focal length 3" - infinity**
- Tracks to **circular** direction smoothly at all speeds and focal lengths
- Tracks **vertically upward** smoothly at all speeds and focal lengths
- Tracks **vertically downward** smoothly at all speeds and focal lengths
- Smooth **convergence** from far to near space
- Smooth **divergence** from near to far space
- Tracks **diagonally upward** with midline pause to refixate
- Tracks **diagonally downward** with midline pause to refixate



- Eyes begin to move independently from **head** to limited upper/lower fields
- Tracks target **horizontally 180°** without midline jerk, **focal length 3" - 6'**
- Continuous **diagonal** tracking **downward** with some jerky movements
- Smooth **convergence** from far to middle space



- Eyes begin to move independently from **head** to limited right/left fields
- Tracks target **horizontally 180°** with midline jerk, **focal length 4" - 5'**
- Continuous **circular** tracking with some jerky movements
- Continuous **vertical** tracking **downward** with some jerky movements
- Continuous **diagonal** tracking **upward** with some jerky movements
- Smooth **divergence** from middle to far space



- Tracks target **horizontally 180°** continuously, overshooting, with midline pause and re-localization, **focal length 5" - 3'**
- Tracks, lingers, and visually searches for target at point of disappearance
- Continuous **vertical** tracking **upward** with some jerky movements
- Beginning **vertical** tracking **downward**, in series of jerky movements, losing and regaining target
- Beginning **diagonal** tracking **upward**, in series of jerky movements, losing and regaining target
- Continuous **convergence** with some jerky movements from middle to near space
- Continuous **divergence** with some jerky movements from near to middle space
- **Compensatory Eye Movements**: eyes remain on stationary target consistently during rapid and extensive voluntary head movements

---

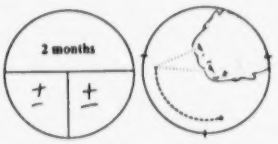
2. c. OCULAR PURSUIT (VISUAL MANIPULATION)

Tracking Movements	Vergence Movements
Eyes remain on target during horizontal, vertical, circular, and diagonal movements	Eyes remain on target during convergence and divergence in all focal lengths

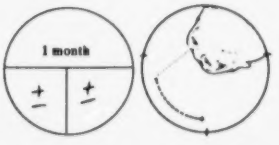
Developmental Levels	
Right	Left

Pattern Components: R | L — Direction (Both Eyes)

Pattern Components: R | L — Eye (Other Occluded)

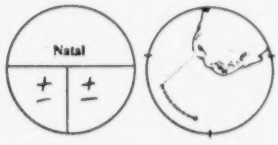


- Tracks target **horizontally 90°** slightly past midline, jerky movements, poor regulation of eye speed to target speed, **focal length 6" - 3'**
- Beginning **circular** tracking in series of jerky movements, losing and regaining target
- Beginning **vertical** tracking **upward** in series of jerky movements losing and regainingtarget
- Beginning **convergence** with short jerks, blinking, and overconvergence within near space
- Beginning **divergence** with short jerks, blinking, and overdivergence within near space
- **Compensatory Eye Movements**: eyes remain on stationary target inconsistently during rapid and extensive voluntary head movements
- Follows target longer during **approach** than **retreat**



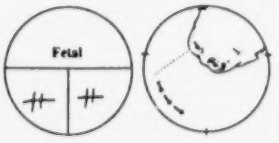
- Tracks target **horizontally 60°** from periphery to midline and back to side, jerky movements, **focal length 7 - 12"**
- Follows target equal distance during **approach** and **retreat**
- **Compensatory Eye Movements**: eyes remain on stationary target during moderate speed and excursions of voluntary head movements

Almost no tracking, rather localization to moving target, loss, and re-localization.



- Eyes and **head** move together during tracking — to the Ⓛ only
- Eyes and **head** move randomly in short lateral excursions — More random eye than head movements
- Tracks target **horizontally 45°** in peripheral field, in series of jerky movements, losing target frequently, difficulty regaining, **focal length 8"**
- Follows target longer during **retreat** than **approach**, between 8 and 12"
- **Compensatory Eye Movements**: eyes remain on stationary target during very slow voluntary head movements in limited range

Tracking worse toward the Ⓡ and in Ⓡ field.



Late Stage (8-9 months)

- Tracks slowly moving target with internal movement horizontally **30°** in peripheral field in **near space**, constantly losing target, able to regain if target pauses

Mid Stage (7-8 months)

- Momentary afterpursuit of slowly moving targets with internal movement (fluttering fingers)

Early Stage (6-7 months)

- Eyes move without purpose, separate from **head**, even under closed lids
- No response to visual target

Assessment Report

2.c. Ocular Pursuits (Visual Manipulation)

Clinical observations: Poor regulation of eye speed to target speed, with skill levels in each eye similar, but the right used more frequently for pursuit;

Tracks slowly moving target horizontally no more than 30 degrees in series of jerky movements, constantly losing the target, able to regain if target pauses; tracking more efficient toward the left than toward the right, with each eye occluded as well as when both were open; eyes unable to separate efficiently from head when moving to the left, eyes and head unable to move together consistently to the left, and eyes lagging behind when moving to the right;

Localization, loss, and relocalization to target moving in vertical and circular directions, rather than true pursuit;

Eyes able to remain on stationary target during slow but not rapid head movements in limited range toward the left (compensatory eye movements);

No convergence or divergence; followed target longer during approach than during retreat

Summary and implications for function: Nathan is able to track a slowly moving target in near space through less than a 30-degree arc in the peripheral field, toward the left better than the right, constantly losing and regaining contact. His eye movements can be described more as localization, loss, and relocalization to the target rather than true pursuit; his right eye appears to be used more frequently, although skill levels are similar. He cannot converge or diverge both eyes on targets approaching or retreating. Poor tracking and vergence movements needed to follow objects and people have interfered with maintaining and regaining attention. Inadequate reciprocal action of paired eye muscles for ocular pursuits reflects the lack of muscular control throughout Nathan's body.

General goal: Ocular pursuits should be worked on at very low and stress-free levels, or abnormal patterns due to excess efforts will increase.

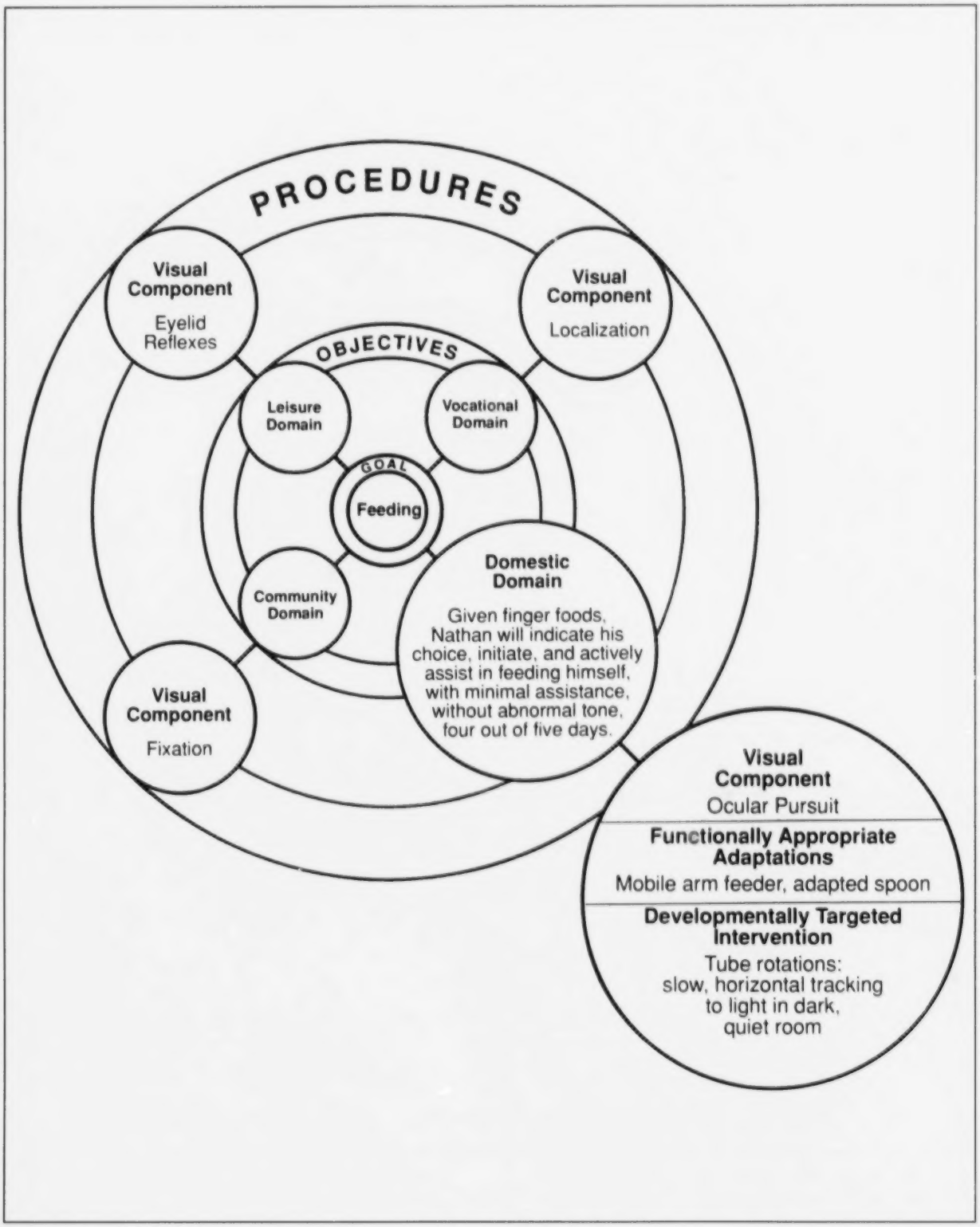


Fig. 10-25

Model for Management of Visual-Motor Dysfunction: Domestic Domain

Model for Management of Visual-Motor Dysfunction (fig. 10-25)

Individualized Management Program

Domestic Domain

Goal: To improve self-help skills

Objective: Given finger foods, Nathan will indicate his choice, initiate, and actively assist in feeding himself, with minimal assistance, without muscle resistance or abnormal tone, four out of five program days.

Visual Component: Ocular pursuit

Visual Present Level of Function: Nathan is able to track a slowly moving target in near space through less than a 30-degree arc in the peripheral field, toward the left better than the right, constantly losing and regaining contact. His eye movements can be described more as localization, loss, and relocalization to the target rather than as true pursuit. His right eye appears to be used more frequently, although skill levels are similar. He cannot converge or diverge both eyes on targets approaching or retreating. Poor tracking and vergence movements needed to follow objects and people have interfered with maintaining and regaining attention. Inadequate reciprocal action of paired eye muscles for ocular pursuits reflects the lack of muscular control throughout Nathan's body. As his grandmother helps him grasp the banana and bring it to his mouth, his tone increases, interfering with smooth, purposeful movements (fig. 10-26).

Visual Procedures

Functionally Appropriate Adaptations: A mobile arm feeder may enable Nathan to feed himself more independently, beginning with finger foods placed in his hand and progressing to an adapted spoon and dish.

Fig. 10-26

Developmentally Targeted Interventions: As one of his classroom aides prepares to feed him at school, Nathan should follow her hand holding the spoon as it moves slowly in an arc from the periphery to midline and then to his mouth, waiting for excessive tone (jaw extension) to subside (fig. 10-27).

Tube rotations recommended by his optometrists to improve pursuit should be done in a noiseless, darkened room, with Nathan semi-reclining or supine, a pillow under his head. A paper towel tube is placed about an inch from Nathan's unpatched eye (to allow observation of his eyeball movements). A penlight or flashlight, with or without colored filters, is placed at the end of the tube, which is moved slowly in a horizontal arc (rotation around the vertical axis of the eye). Nathan should be allowed to move his eyes and head together, or eyes separate from stabilized head, whichever allows him to achieve a fovea-to-target match (fig. 10-28).

Fig. 10-27

Fig. 10-28

2. d. GAZE SHIFT (VISUAL RELEASE)

Developmental Levels	
Right	Left

Pattern Components	
R	L
Direction	

Functional Focal Lengths
Near space: 3 - 12" Middle space: 1 - 6' Far space: 6 - 20' Distant space: 20' - infinity

Shift Gaze: eyes move from one target to another within same focal length or between different focal lengths

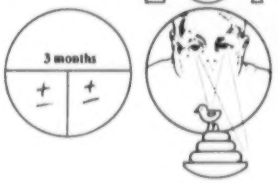
Alternate Glance: between 2 targets
Scanning: between 3 or more targets

Scans 3 or more targets within **all focal lengths** quickly and accurately
Eyes move independently from **head** to shift gaze
Alternates glance between 2 targets in **same focal length** within **far space** easily
Shifts gaze between targets in **near** and **far space** quickly and accurately
Shifts gaze within and between **all** focal lengths without **blinking**
Shifts gaze easily during adaptive interaction of **eye/hand/mouth**: regards target, grasps, mouths, withdraws, regards, manipulates, releases, resecures, etc.

Alternates glance between 2 targets in **same focal length** within **middle space** easily
Alternates glance between 2 targets in **same focal length** within **near space** easily
Shifts gaze between targets in **middle** and **far space** accurately
Shifts gaze between targets in **near** and **middle space** accurately
Scans 3 or more targets in **middle space** quickly but inaccurately
Eyes begin to move independently from **head** to shift gaze
Shifts gaze between **near** and **far space** (releases fixation) during adaptive interaction of eye/**hand**/mouth (grasping, manipulating, mouthing target)

Conjugate Deviations: eyes consistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **far space** inaccurately
Scans 3 or more targets in **near space**, overshooting, re-localizing
Tenacious fixation interferes with smooth release (**alternate glance**) in **near space**
Shifts gaze between targets in **near** and **middle space** inaccurately
Shifts gaze between targets in **near** and **far space** with **blinking** and eye-rolling
Shifts gaze from **surroundings** to target in own **hand** after mouthing

Uses (L) eye in (L) Field and (R) eye in (R) Field



Conjugate Deviations: eyes inconsistently move together voluntarily
Alternates glance between 2 targets in **same focal length** within **middle space** inaccurately
Begins to shift gaze between targets in near and middle space slowly, with difficulty
Eyes and **head** move together consistently during voluntary gaze shifts
Shifts gaze between own **hand** and target during approach
Alternates glance between target placed on surface and **hand** withdrawn
Shifts gaze consistently without **blinking** between targets in same focal length.

---

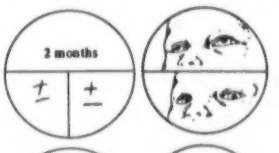
2. d. GAZE SHIFT (VISUAL RELEASE)

Conjugate Deviations: eyes move together in same direction at same time (yoked)

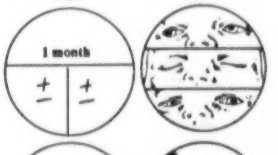
Components of Gaze Shift (Alternate Glance or Scanning)
1. Release of fixation on target 2. Re-localization on next target 3. Repeat

Developmental Levels	
Right	Left

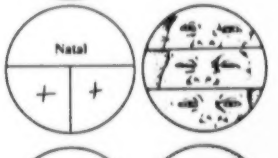
Pattern Components	
R	L
Direction	



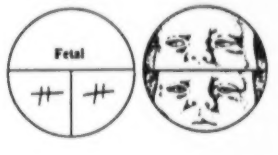
Conjugate Deviations: eyes move voluntarily more than involuntarily (randomly)
Conjugate Deviations: eyes move separately during primarily voluntary gaze shifts
Shifts gaze in **same focal length** in **near space**, inaccurately, overshooting target
Shifts gaze from own **hand** to **surroundings** (releases fixation)
Shifts gaze consistently without **blinking** during involuntary gaze shifts
Shifts gaze inconsistently without **blinking** during voluntary gaze shifts (release of focal fixation)
Focal fixation not sustained enough to require blink during gaze shift



Conjugate Deviations: eyes move separately during beginning voluntary gaze shifts
Conjugate Deviations: eyes move together during primarily involuntary gaze shifts
Eyes and **head** move together inconsistently during beginning voluntary movements
Blinks consistently during release of ambient fixation (stare at surroundings)
Analysis: → (L): eyes shift first, then head moves, then eyes move again
(R) ← : head moves, eyes lag, head turns more



Conjugate Deviations: eyes move together during involuntary gaze shifts
Eyes and **head** move together during random movements of both
Blinks inconsistently during release of ambient fixation (stare at surroundings)



Mid Stage (7-8 months)
No **eye/hand** interaction during eye movements
Random, sluggish **blinks** during eye movements
Involuntary **gaze shifts** between **different focal lengths**
Involuntary **gaze shifts** in **same focal length**

Early Stage (6-7 months)
Conjugate Deviations: eyes move co-jointly in all directions during involuntary movements even under closed lids
Eyes move independently from **head** during random movements of both

Assessment Report

2.d. Gaze Shift (Visual Release)

Clinical observations: Many involuntary gaze shifts;

Inconsistent conjugate deviations (eyes yoked together during most involuntary shifts, but moving separately during voluntary shifts);

Eyes and head move together inconsistently during all gaze shifts (toward the left: eyes shift first, then head moves, then eyes move again; toward the right: head moves, eyes lag, head turns more);

Difficulty alternating glance between two targets in same focal length in near space (slow and inaccurate, with overshooting), worse toward the right than the left;

Slow, labored shifts from target in one focal length to another (near to middle or far space);

No functional scanning movements (shifts between three or more targets);

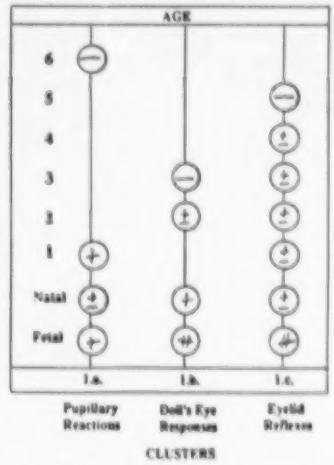
Extremely limited eye-hand interaction between own hand and target during approach

Summary and implications for function: Involuntary, slow, and inaccurate gaze shifts have interfered with alternating glances from desk to teacher or chalkboard in classroom. Complex scanning movements needed for reading were essentially nonfunctional. Nathan's gaze shifts are actually a series of slow, separate localizations and relocalizations.

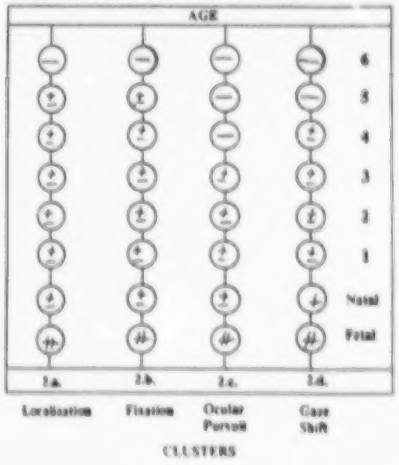
General goal: No recommendations for formal programming at this time. Emphasis should be on improvement of localization and relocalization skills rather than rapid complex gaze shifts.

Score Sheet (Developmental Levels)

Section 1. Primarily Involuntary Visual Patterns (Reflexive)



Section 2. Primarily Voluntary Eye Movements (Cognitively-directed)



Summary

Periodic Blink: 2 per minute
SECTION 1. Primarily Involuntary Visual Patterns (Reflexive) 0-4 months
SECTION 2. Primarily Voluntary Eye Movements (Cognitively-directed) 0-5 months

Subject: Nathan J Examiner: Erhardt Test Date: 12/88 and 1/89

Birthdate: 4/18/80 Chronological Age: 8½ years Diagnosis: Cerebral Palsy

Assessment Report

Summary and conclusions: Significant reflexive immaturity affects Nathan's functional vision as involuntary doll's eye responses interfere with voluntary eye-head movements, especially localization to the right field and downward gaze. Delayed defensive blink correlates with his long latency period for voluntary motor response.

Preference for left hand use has resulted in decreased visual orientation to the right and subsequent widening of the discrepancy between skill levels on each side. Visual localization to and identification of objects in middle and far space has not fully developed because of Nathan's physical mobility limitations (no linkage of what is seen with what is then touched) and his compensatory use of sound and movement clues.

Nathan's monocular fixation, right eye preferred, with vision in the other eye suppressed to avoid diplopia, is a common physiological adaptation to the inability of both eyes to align. Fixation is brief. Nathan relies on visual memory rather than careful inspection of visual targets. No eye-hand monitoring is possible unassisted, except in the ATNR position. Fixation on objects at the side, especially the left, is easier than on those in midline because of poor head control.

Moving targets stimulate a visual response from Nathan that can be described as a series of localizations and relocalizations rather than true pursuit because of poor coordination of paired eye muscles. No convergence is possible because only one eye is used at a time.

Gaze shifts can also be described as localization and relocalization, since the temporal lapse is so prolonged. Particularly slow and difficult are shifts from one focal length to another (near/far/near).

Comparison with Nathan's previous evaluation (January 1986) shows the following changes, related to intervention at home and school:

1. Increased integration of the doll's eye response during head extension, flexion, and rotation toward the left, but not toward the right
2. Significant improvement in the immediacy and consistency of defensive blinks in both central and peripheral fields (almost nonexistent previously), but still delayed for small targets
3. Better ability to detect targets by movement and contour rather than sound alone in middle space.
4. Fixation on faces sustained up to seven seconds, compared with brief glances previously
5. Able to track a slowly moving target in near space through an approximate 25-degree arc in peripheral field, toward the left better than the right, constantly losing and regaining contact; previously was totally unable to follow a moving target
6. Slight improvement in shifting gaze from one focal length to another, with shifts in same focal length still slow and inaccurate

General recommendations: Developmentally targeted intervention designed to stimulate more rapid responses to automatic, reflexive action can contribute to shorter latency periods for voluntary movements. At the same time, better voluntary control would help integrate primitive reflexes contaminating volitional movements. In order to improve body symmetry, prevent deformities, and access more visual and physical options, Nathan needs to orient more frequently to the right field.

Increased localization and fixation on objects in the right field and middle space should be stimulated with functionally appropriate adaptations such as Nathan's new powered chair with right-hand switch and positioning of Nathan and the stimuli in his environment.

Activities designed to decrease reliance on sound and movement for localization will encourage more use of the eyes for discrimination and identification. Socially motivating games can also be used to increase duration of fixations.

Basic vision training, carefully structured to achieve optimal fovea-to-target match, can be reinforced with developmentally appropriate interventions to encourage tracking of slowly moving targets, with head stabilized for more accurate eye movements.

Nathan needs a great deal of time to accomplish functional gaze shifts, as well as all visual-motor skills. Since this time lag (latency period) may not significantly improve, intervention should stress *accuracy* rather than *speed*.

Re-evaluation is recommended in one year.

Signature

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Chapter Eleven
Summary

The eye and the hand are the father and mother of artistic activity.
(Arnheim 1974, 171)

A Synthesis of Models for Visual-Motor Assessment and Management

Assessing and managing the visual function of children with multiple impairments is a challenging venture for all professionals, whose own learning process often involves new and unfamiliar theories, terms, and techniques. Bloom's taxonomy of the cognitive domain can be used to describe this learning process in a hierarchy of steps leading to synthesis: knowledge and comprehension (data collection), analysis (priority selection), and application (program development and implementation) (Bloom 1956). Because a variety of disciplines are represented in the transdisciplinary team, a holistic view of the child is best achieved by an eclectic approach embracing medical, educational, developmental, and functional models. Synthesis occurs when all the components of vision within those models are considered and included in the therapeutic planning process, as team members share information and use intuitional skills combined with clinical judgment to achieve goals (Smith and Cote 1982). The development of comprehensive programs to help the child reach his or her visual potential begins with data collection.

Data Collection (Knowledge and Comprehension)

Medical. Medical records report birth history, visual pathology, acuity and prescriptive lenses, eye surgeries, and medications with ocular side effects. This basic information helps determine if visual deficits are static and irreversible, and thus not amenable to positive change and requiring functionally appropriate adaptations.

Educational. The Individualized Educational Plan (IEP) contains numerical or descriptive functional levels in selected domains, as well as goals and objectives. This information is needed to determine if the visual deficits will interfere with the child's primary occupational role, that of a learner.

Developmental. A variety of assessments identify developmental levels in areas such as cognition, communication, motor, social, and visual motor. The developmental pinpoints can establish the child's exact position in all sequences of skill development, since vision is not an isolated sense and needs to be considered as affecting all areas of development. Intervention can then match the child's needs, and progress can be modified in response to performance data collected over time (ongoing re-assessment) (Haring 1975). This information helps determine if the visual deficits are in a state of dynamic process and thus responsive to developmentally targeted interventions.

Functional. Assessment and task analysis of activities in the child's home, school, and community environments provide data essential for choosing priorities. This information helps determine which visual skills are required for participation in integrated environments with nonhandicapped peers.

Priority Selection (Analysis)

This decision-making process involves the entire IEP team, which always includes the parents or other caregivers and the child if possible. Visual skills targeted for intervention must be relevant to daily living skills, contribute to optimal independence in integrated environments, and be taught within the context of those environments. To have educational validity, the skills should be ones that can be generalized, that is, ones that enhance participation in multiple environments. To have social validity, the skills should have significance to the individual and to his or her peers (Snell and Browder 1986).

Long-term goals should be considered early and include not only those needed at the present time but also those that will be needed as the child becomes an adult. By projecting at least several years ahead, probable changes can be anticipated in school placement or in life roles toward new levels of independence and employment (Goodwyn 1987).

Program Development and Implementation (Application)

The logical synthesis of theories and practices of every professional working with a handicapped child culminates in a holistic model of management as well as assessment. This model recognizes interrelationships among different sets of data, facilitates communication among disciplines, and focuses intervention on the use of vision for optimal interaction with the environment. If objectives are written to reflect the interrelationships among domains, programming will follow the same patterns. For example, improved eye-hand coordination can be achieved only with recognition of the impact of visual deficits on fine-motor development, and conversely, that of delayed hand skills on visual attention (McDonnell 1989).

Children with Cerebral Palsy: Educational Implications of Visual Dysfunction

Case studies of three children with visual-motor problems related to their type and degree of cerebral palsy have been presented to illustrate theoretical approaches, assessment procedures, and management strategies. Joseph, with moderate physical handicaps, has visual pathology originating from medical problems during and after premature birth. Melinda, mildly involved physically, displays perceptual deficits that interfere with academic progress. Nathan, whose motor skills are severely delayed, requires technological adaptations to participate in his integrated classroom.

Related services such as occupational therapy provide therapeutic interventions that these children need in order to benefit from special education. Emphasis must be on functional skills that are critical, interactional, and can be generalized (Campbell and Wetherbee 1988).

Unquestionably, the most critical skill, which is also the most interactional and easily generalized, is communication. Various forms of communication are available to the general population, but children with cognitive or motor handicaps may have limited choices or need special adaptations.

Joseph, Melinda, and Nathan have each compensated in different ways for visual and physical problems caused by interruption of their normal development process. They each attempt to use their vision as effectively as possible, despite decreased acuity, reflexive influences on voluntary eye movements, and imperfect oculomotor control, by making postural compensations to achieve functional communication.

For *writing*, Joseph uses a total flexor synergy to gain postural stability for better arm and hand mobility. Nearsightedness, field losses, and nystagmus dictate certain head positions. Head movements trigger the doll's eye response, interfering with eye-hand coordination. Recommended functional adaptations and new visual interventions included alternative seating and work surfaces, and prisms added to his corrective lenses, shifting his visual field to the right and rotating it for a more midline and horizontal orientation.

For *reading*, Melinda stabilizes with asymmetrical neck extension to gain postural stability for ocular motility; thus she has difficulty with downward gaze. Despite minimal farsightedness, Melinda is unable to sustain focus without visual fatigue, and the doll's eye response is elicited when she rotates

her head to the left, interfering with her eyes returning to the beginning of the next line of print during reading. Her method of choice for securing head support (chin on hand) is considered a functionally appropriate adaptation. New visual interventions included amber lenses to correct glare and bifocals to stabilize focus at near point.

For *computer* use, Nathan stabilizes with the asymmetrical tonic neck reflex (ATNR) to gain postural stability for arm movement to activate the single switch. Significant farsightedness prevents clear focus on the screen, and head turning to the right (from switch to screen) causes his eyes to lag, thus requiring excessive head turning to bring the screen into his visual field. A recommended adaptation was to place the switch closer to midline to reduce head and arm movement. New visual interventions included corrective lenses and a patching regime for ocular motility training.

Figure 11 presents a graphic example of the synthesis of models for visual-motor assessment and management.

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Fig. 11

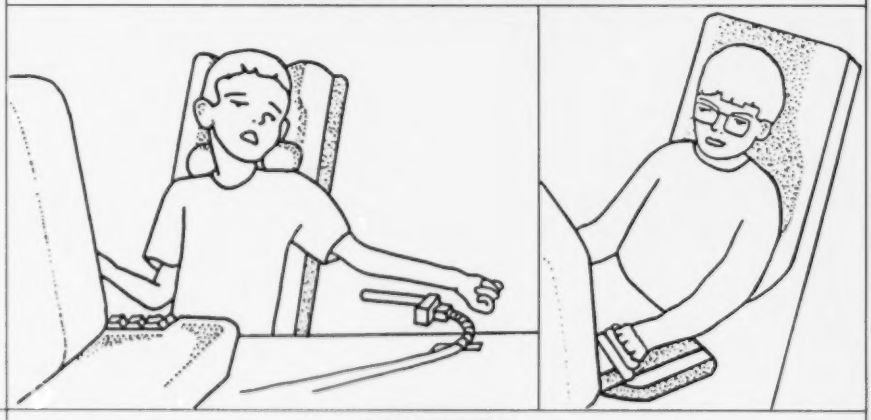
Postural Compensations, Visual Components, Educational Implications of Delayed Reflex Integration, Functional Adaptations, and Visual Interventions for Communication Skills in Children with Cerebral Palsy

Postural Compensations	Stabilizes with asymmetrical tonic neck reflex (ATNR) position
Visual-Motor Components **Involuntary Reflexes (Doll's Eye)**	Eyes lag when head flexes, extends, or rotates to the right
Voluntary	Eyes inconsistently move with head toward the left
Visual Acuity Components	Hyperopia. +5.50 O.D. (right eye) and +4.50 O.S. (left eye)
Educational Implications	For **localization** of **computer** switch, uses excessive head rotation, then extends head to bring eyes down. Elbow extends to activate switch, other arm flexes (ATNR). Eyes and head then relocalize to computer screen. Head rotation to the right causes eyes to lag behind (doll's eye).
Functional Adaptations	Needs switch placed close to midline, activated by minimal arm movement forward against round switch. Minimal head movement decreases reflexive influences. Eyes remain fixated on screen.
New Visual Interventions	Corrective lenses for hyperopia: +5.50 O.D. and +5.00 O.S. Patching regime for ocular motility training only.

Scoring Key

- ⊕ Present
- ± Emerging
- ⊖ Absent
- ⊕⊕ Transitional (Replaced)
- ○ Norm

CEREBRAL PALSY—SEVERE



CLUSTER 1.b.
Doll's Eye response

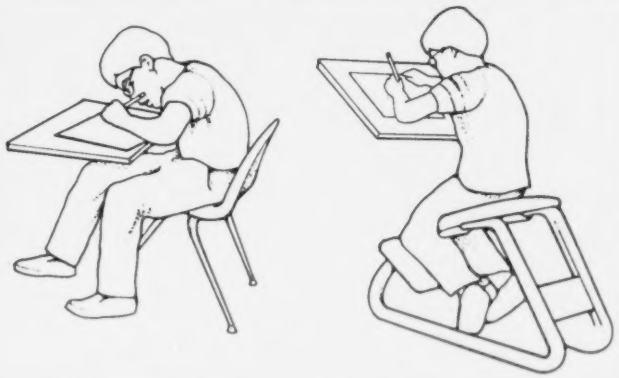
3

MONTHS

2

COMPUTER

R L Direction	R L Eye
⊖⊖ Eyes move in same direction as head **rotation:** Integrated	⊖⊖ Eyes move in same direction as head **flexion:** Integrated
	⊖⊖ Eyes move in same direction as head **extension:** Integrated
⊖⊕ Delayed or inconsistent eye movement in same direction as head **rotation:** Beginning Integration	⊖⊖ Delayed or inconsistent eye movements in same direction as head **flexion:** Beginning Integration
	⊖⊖ Delayed or inconsistent eye movements in same direction as head **extension:** Beginning Integration

Stabilizes with total body flexion	Stabilizes with asymmetrical neck extension
Eyes lag during all head movements of flexion, extension, and rotation to right and left	Eyes lag when head flexes or rotates to the left
	Eyes move with head into extension or to the right
Myopia. 20/200 O.S. with corrective lenses -14.25 O.D. and -13.75 + 1.25 x 086 O.S. Nystagmus. Right hemianopsia. Cataract in right eye.	Hyperopia. 20/25 O.U. (far). 20/30 O.D. and 20/60 O.S. (near). Difficulty sustaining focus. Photophobia.
For **ocular pursuit** of moving hand during **writing,** uses total flexor synergy at near space, head rotated to the right and tilted to the left to optimally position residual left field of left eye and find null point of nystagmus.	For **gaze shift** during **reading,** uses head extension and rotation to the right for better voluntary control. Difficulty keeping both eyes and head in downward gaze. Eyes lag behind head rotating to the left (returning to the beginning of next line).
Needs alternate seating for spinal extension, and face parallel and close to elevated and inclined writing surface.	Needs to choose comfortable and stable positioning, with chin supported by hand, if necessary, to allow eyes to move separately from head.
Prisms to shift visual field to the right and rotate it to bring the vertical left field toward midline and into horizontal orientation.	Amber lenses to counteract glare. Bifocals: sphere for distance and +1.25 add to stabilize accommodation (focus) at near point.
CEREBRAL PALSY—MODERATE	**CEREBRAL PALSY—MILD**
	
WRITING	**READING**
R L **Direction** (−)(−) **Rotation:** Integrated (+)(+) **Rotation:** Beginning Integration	R L **Eye** (−)(−) **Flexion:** Integrated (−)(−) **Extension:** Integrated (+)(+) **Flexion:** Beginning Integration (+)(+) **Extension:** Beginning Integration
R L **Direction** (+)(−) **Rotation:** Integrated (++)(+) **Rotation:** Beginning Integration	R L **Eye** (−)(−) **Flexion:** Integrated (+)(+) **Extension:** Integrated (+)(+) **Flexion**: Beginning Integration (++)(++) **Extension:** Beginning Integration

Glossary

Accommodation: adjustment of the lens curvature by contraction or relaxation of ciliary muscles to bring images at various distances into sharp focus on the retina

Alternating Monocular (Biocular) Fixation: fixation alternating between the two eyes

Amblyopia: reduced visual acuity not correctable by refractive methods (application of lenses), usually as a result of strabismus, unequal refractive error, or inadequate early stimulus

Amblyoscope: an instrument that determines the level of binocular perception or grades of fusion

Ametropia: refractive error of the eye

Anisometropia: unequal refractive state of the two eyes with one requiring a different lens correction from that of the other

Anomalous (Abnormal) Retinal Correspondence (ARC): an abnormal adaptation, usually in response to an ocular muscle imbalance, in which the two foveas do not correspond in spatial direction

Astigmatism: refractive error that prevents light rays from coming to a point of focus on the retina, caused by unequal degrees of refractive power in the various meridia of the cornea

Asymmetrical Tonic Neck Reflex (ATNR): an obligatory response, when the head is turned, of face-arm extension and skull-arm flexion

Bifocal Lens: a spectacle lens of two portions having different focal powers, the upper for distance vision and the lower for near

Binocular Fixation: ability to use the two foveas of the eyes simultaneously to focus on a target and fuse the two images into a single perception, giving a correct interpretation of its position in space and its solidity (depth perception)

Blindness (Legal Definition): corrected visual acuity of 20/200 or less, or a visual field diameter of no more than 20 degrees, in the better eye

Cataract: partial or complete loss of transparency of the lens

Central Visual Field: area of the visual field corresponding to the macula

Central Vision: ability of the eye to perceive a target in the direct line of vision

Cerebral Palsy: disorder of movement and posture resulting from a nonprogressive abnormality of the immature brain

Ciliary Muscle: a ring of muscle that constricts around the crystalline lens, increasing its convexity

Clinical Perimetry: measurement of the visual fields

Cochleo-Palpebral Reflex (Auditory): momentary blinking or eyelid tensing in response to an unexpected sharp noise

Cognition: the act of perceiving and knowing

Compensatory Eye Movements: eyes staying on stationary target during active head movements

Concave Lens: lens that is thicker at the edges than the center, having the power to diverge light rays, used to correct myopia, and designated by the minus sign (-)

Conceptional Age: gestational age plus age from birth

Cones: light-sensitive cells located primarily in the central retina, responding best to bright light, and sensitive to fine detail and color

Conjugate Gaze or Deviations: symmetrical movements of the eyes in the same direction at the same time

Consensual Reflex: light directed into one pupil resulting in similar constriction in the other

Contour Resolution: identification of form outline

Convergence: process of using extraocular muscles to direct the visual axes of the two eyes to a near point (simultaneous turning of the eyes inward)

Convex Lens: lens that is thicker at the center than at the edges, having the power to converge light rays, used to

correct hyperopia and furnish additional power for reading, and designated by the plus sign (+)

Cornea: the transparent outer coat of the eyeball through which light rays pass

Cortical Visual Impairment: visual loss resulting from damage to the visual cortex, usually without internal pathology of the eye

Countertorsion: apparent movement of the eyes in the opposite direction that the head is turned

Defensive Blink to Threat: reflexive sudden closure of the eyelids in response to a visual stimulus presented abruptly

Development: result of interaction between evolution, maturation, and learning

Diabetic Retinopathy: disease of the retina associated with diabetes mellitus, resulting in fluctuating or loss of vision

Diopter: a unit of measurement of lens power that will bring parallel light rays to a focus at one meter; for example, a 1 D diopter will focus light at one meter

Diplopia (Double Vision): a condition in which a single target is perceived as two targets, usually because of ocular disalignment

Divergence: process of using extraocular muscles to direct the visual axes of the two eyes to a point further away (simultaneous turning of the eyes outward)

Doll's Eye Response: countertorsion of eyes in opposite direction of head turned in a horizontal or vertical plane

Duction: pursuit or following movement of one eye

Dyslexia: inability to read or obtain information from printed symbols commensurate with intelligence level

Emmetropia: the condition of an infinitely distant target imaged sharply on the retina without accommodation (no refractive error of the eye)

Encephalogram: brain wave pattern

Esophoria: tendency of the eyes to turn inward

Esotropia (Convergent Strabismus): inward turning of the eyes

Exophoria: tendency of the eyes to turn outward

Exotropia (Divergent Strabismus): outward turning of the eyes

Extraocular Muscles: six eye muscles, attached to each globe, that move the eyeball

Eye-Neck Reflex: opisthotonos (arching back) in response to bright light directed into eyes when head is erect and unsupported

Fixation: movement of the eye in such direction of gaze that the image of the target falls on the fovea and is sustained there

Focal Length: the distance from the point of focus to the surface of the lens

Focus: point at which rays meet after reflection or refraction (noun); the ability to accommodate (verb)

Fovea Centralis: depression in the center of the macula where vision is most acute (highest concentration of cones)

Fundus: interior of the eye visible through an ophthalmoscope

Fusion: power of the brain to combine the two images, received simultaneously by the two eyes, into a single mental image

Hemianopsia: blindness in one half of the visual field of one or both eyes

Heterophoria: tendency of the lines of sight to deviate from the relative positions necessary to maintain single binocular vision for a given distance of fixation

Heterotropia (Strabismus): deviation of the eyes from the normal straight position

Hippus: constant small, abnormal, rhythmic, irregular constrictions and dilations of the pupil

Hydrocephalus: imbalance between secretion and absorption of cerebrospinal fluid, with obstruction causing increased pressure inside the brain

Hyperopia, Hypermetropia (Farsightedness): refractive error in which the focal point for light rays from a distant object is posterior to the retina when accommodation is at rest

Hyperphoria: tendency toward upward deviation of one eye with reference to the other eye

Hypertropia (Strabismus): upward deviation of the nonfixating eye with reference to the fixating eye

Intraventricular Hemorrhage (IVH): bleeding into the ventricles

Iris: colored circular membrane suspended behind the cornea and immediately in front of the lens, perforated by the pupil; regulates the amount of light entering the eye by changing the size of the pupil

Latency: the time of occurrence after stimulus onset

Lateral Geniculate Nucleus: a region of the brain located in the thalamus that receives signals from the optic nerve

Learning Disability: deficits in perceptual, integrative, or expressive processes that severely impair learning efficiency in children with adequate mental ability, sensory processes, and emotional stability

Lens (Crystalline): transparent resilient structure suspended in the eyeball between the aqueous and vitreous, furnishing the additional focusing power needed to bring light rays to a focus on the retina

Light Perception: ability of the eyes to distinguish the presence or absence of light

Low Vision: best corrected visual acuity is less than normal

Macula: area of the retina surrounding the fovea, with the fovea comprises the area of most acute vision

McCarthy's Reflex: tapping supraorbital area of each eye (above eyebrow) results in homolateral blink

Midline Jerk: a momentary loss of fixation in tracking at the point equidistant between the two eyes

Minimal Brain Dysfunction: an individual with near average, average, or above average intelligence with learning or behavioral disabilities associated with deviations of central nervous system function

Monocular Fixation: ability to direct the fovea to a target and maintain the match with one eye only, with vision in the other absent, disregarded, or suppressed

Moro Reflex: a postural startle reaction resulting from dropping of the head backward

Myopia (Nearsightedness): refractive error in which the focal point for light rays from a distant object is anterior to the retina when accommodation is at rest

Naso-Palpebral Reflex: bilateral blink in response to tapping on the bridge of the nose

Near Point of Convergence (NPC): the point of intersection of the lines of sight when the eyes are in the position of maximum convergence, normally about 3" from the eyes

Near Vision: the ability to perceive distinctly targets at normal reading distance, about 14" from the eyes

Normal Retinal Correspondence (NRC): the unified perception of a binocularly viewed target, as the foveae of the two eyes have common lines of direction

Null Point: distance from the position of the eyes where nystagmus is dampened or minimal

Nystagmus: involuntary oscillatory movements of the eyeballs in horizontal, vertical, rotatory, or mixed alternate directions

Occipital Lobes: vision center of the brain

Occlusion Therapy: covering one eye to encourage use of the other

OD: Oculus dexter (right eye)

Ontogenesis: development of an individual organism

Ophthalmologist: a physician specializing in ophthalmology, the profession concerned with medical and surgical care of the eye

Ophthalmoscope: an instrument for viewing the fundus and interior of the eye

Optic Atrophy: degeneration of optic nerve fibers with visual loss proportional to the amount of fibers destroyed

Optic Nerve: the nerve carrying visual impulses from the retina to the brain, where images are formed

Optician: a person who grinds lenses, fits them into frames, and adjusts the frames to the wearer

Optokinetic Nystagmus (OKN): physiological nystagmus induced by the attempt to fixate targets rapidly traversing the visual field

Optometrist: person qualified to practice optometry, the profession concerned with evaluation of ocular health, the refractive states of the eye, selection of optical corrective aids, and training methods for the enhancement of visual performance

Orthoptist: person who practices orthoptics, the training process for improvement of the coordination of the two eyes for efficient binocular vision

OS: Oculus sinister (left eye)

OU: Oculi unitas (both eyes)

Palpebral: pertaining to the eyelid

Peripheral Visual Field: entire visual field exclusive of that corresponding to the macula

Peripheral Vision: ability to perceive presence and motion of targets outside the direct line of vision

Phosphenes: subjective images generated within the eye and brain rather than by external light, induced by mechanical or electrical stimulation of the eyeball

Photophobia: excessive discomfort and sensitivity to light

Photoreceptors: receptor activated by light stimuli (rods and cones)

Phylogenesis: development of an animal species

Plano Lens: a lens having no dioptic power

Preferential Looking (PL): an evaluation method based on the assumption that an infant will fixate on a patterned rather than homogenous field, with an observer recording the number and duration of fixations on each stimulus

Presbyopia: a reduction in accommodative ability caused by loss of elasticity of the crystalline lens, occurring normally with age, requiring a plus lens addition for near vision

Preterm: infant born at gestational age of less than 40 weeks (term)

Prism: a solid wedge of glass or plastic that displaces the direction in which light rays enter the eye

Prism Diopter: a unit of measurement specifying the amount of deviation of light by an ophthalmic prism; for example, a 1 prism diopter will deviate light 1 centimeter at a distance of 1 meter; one degree = 2 prism diopters

Pupil: opening or aperture in the center of the iris through which light enters the eye

Pupillary Reaction: constriction or dilation of the pupil in response to stimulation of the retina

Recession: surgery for strabismus in which the insertion of a muscle is moved backward, thus decreasing its action

Refraction: (1) the bending of light rays in passing from one transparent medium into another of different optical density, (2) determination of refractive errors of the eye and correction by prescriptive lenses

Refractive Error: condition of the eye in which light rays from stimuli are not brought to a single focus exactly on the retina

Resection: surgery for strabismus in which the insertion of a muscle is moved forward, thus increasing its action

Retina: anterior coat of the eye, formed of light-sensitive nerve fibers and connected with the optic nerve

Retinopathy of Prematurity (ROP): retinal disease of premature infants, characterized by vascular proliferation, intraocular hemorrhage, retinal edema, detachment, and formation of dense fibrous tissue in its advanced stages

Retinoscopy: objective medical evaluation of the eye's refractive properties

Rods: light sensitive cells located primarily in the peripheral retina, sensitive to movement and light, even low intensity

Saccade: a rapid change of fixation from one point in the visual field to another

SC (Sine Correction): without corrective lenses

Scanning: a series of rapid eye movements used to explore the details of visual stimuli in a large area

Stereopsis: the binocular appreciation of depth

Strabismus: inability of the two eyes to simultaneously direct gaze to the same target for binocular fixation because of an ocular muscle imbalance

Suppression: an adaptation an individual makes to eliminate the confusion of diplopia, caused by ocular disalignment, in which the input to the strabismic eye is subconsciously ignored

Tracking: ability to follow horizontal, vertical, circular, or diagonal movements of targets with smooth pursuit eye movements

Vergence: movement of the eyes in opposite directions, convergence (both moving toward midline) or divergence (both moving away from midline)

Version: parallel smooth movement of both eyes

Vision: the process of seeing (sight)

Visual Acuity: a descriptive means of expressing the sharpness, clearness, and distinctness of vision

Visual Cortex: part of the brain specializing in interpretation of visual signals

Visual Field: the entire area that can be seen while the eye is fixing or gazing steadily at a target in the direct line of vision

Visual Memory: ability to remember a visual image no longer present

Visual Perception: the capacity to interpret sensory input, recognize similarities and differences, and assign meaning to what is seen through the sense of vision

Visually Evoked Potentials (VEP): the electrical discharge occurring in the visual cortex in response to brief visual stimuli

Visuo-Palpebral Reflex: blink or eyelid closure in response to bright light directed into eyes

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